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ENGINEERING:

An Illustrated Weekly Journal.

EDITED BY WILLIAM H. MAW AND ALEX. RICHARDSON.

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Aveling & Porter, Ltd.,
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ON ADMIRALTY AND WAR OFFICE LISTS.
ENGINES for Torpedo Boats, Yachts, Launches.
BOILER FEED PUMPS.
See advertisement page 18.
PATENT WATER-TUBE BOILERS.
AUTOMATIC FEED REGULATORS.
And Auxiliary Machinery as supplied to the Admiralty. 2179

Dredging Plant
OF ALL DESCRIPTIONS.
FLOATING CRANES. COAL BUNKERING VESSELS.
Werf Conrad, HAARLEM, HOLLAND.
Agents: MARINE WORKS, LTD., FRIARS HOUSE, 39-41, NEW BROAD ST., LONDON, E.C.2.
See half-page Advert., last week and next week. 1382

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GEORGE RUSSELL & CO., LTD., Motherwell. 1867

STEEL TANKS, PIPES, GASHOLDERS, &c.
Thos. Piggott & Co., Limited,
BIRMINGHAM. 1241
See Advertisement last week, page 88.

Spencer-Hopwood & Kirke
PATENT BOILERS *See Page* 88. 1293
Sole Makers: SPENCER-BONECOURT, LTD.,
Parliament Mansions, Victoria St., London, S.W.

Tank Locomotives.
Specification and Workmanship equal to Main Line Locomotives.
R. & W. HAWTHORN, LESLIE & CO. LTD., ENGINEERS, NEWCASTLE-ON-TYNE. 1864

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CLUTHA WORKS, GLASGOW.
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RAILWAY CARRIAGES AND WAGONS
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Hammers, Presses, Furnaces,
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Gas Engines Inspected, Tested and Reported upon. Over 25 years' experience. Tel.: Maryland 1736 & 1737. Wire: "Rapidising, London."
—Great Eastern Road, Stratford, E. 15. 1794

Fuller, Horsey, Sons & Cassell.
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In the
SALE AND VALUATION
of 1834
PLANT AND MACHINERY
and
ENGINEERING WORKS.
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Iron and Steel
Tubes and Fittings.
Sole Licensees in Great Britain for the manufacture of "Armco" Rust and Corrosion Resisting Iron Tubes. 817
The Scottish Tube Co., Ltd.,
HEAD OFFICE: 34, Robertson Street, Glasgow.
See Advertisement, page 77, Feb. 1.

YARROW & CO. (1922), LTD., GLASGOW.
PASSENGER AND CARGO STEAMERS.
SHALLOW DRAFT VESSELS. 1553

Campbells & Hunter, Ltd.
Gear Cutting.
Worm Wheels cut up to 13 ft. diam.
Bevel and Mitre Wheels planed up to 3 ft. diam.
Spur Wheels cut up to 9 ft. diam
DOLPHIN FOUNDRY, LEEDS. 4547

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PORTSMOUTH,
SHIP & LAUNCH BUILDERS, Od 3551
ENGINEERS & BOILER MAKERS.

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Hurst, Nelson & Co., Ltd.,
Builders of RAILWAY CARRIAGES, WAGONS ELECTRIC CARS, and EVERY OTHER DESCRIPTION OF RAILWAY and TRAMWAY ROLLING STOCK.
Makers of WHEELS and AXLES, RAILWAY PLANT, FORGINGS, SMITH WORK, IRON & BRASS CASTINGS.
PRESSED STEEL WORK OF ALL KINDS.
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OIL FUEL APPLIANCES,
Systems
PRESSURE, AIR, STEAM
For Boilers of all types.
KERMODES LIMITED,
35, The Temple, Dale Street, Liverpool.
Naval Outfits a Speciality,
also for Merchants Ships, for Factories, Locomotives, and Industrial Process Furnaces of all kinds.
Supplied to the British and other Governments.
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Locomotives Tank Engines
designed and constructed by
MANNING, WARDLE AND COMPANY, LIMITED,
Boyne Engine Works, Leeds. Od 3487
See their Illus. Advertisement, page 91, last week.

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THE GLASGOW ROLLING STOCK AND PLANT WORKS, MOTHERWELL. Od 3383

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BUILDERS of RAILWAY CARRIAGES & WAGONS
MAKERS of WHEELS and AXLES of all kinds.
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Chief Works and Offices:
WISHAW, near GLASGOW.
London Office: Od 3353
3, VICTORIA STREET, WESTMINSTER, S.W.

Patents and Trademarks:—
Inventors Advice, Handbook and Consultations free.—KINGS PATENT AGENCY, LTD. (P. T. King, Director), 146a, Queen Victoria Street, London. 36 years' refs. 1209

Rosser and Russell, Ltd.,
MECHANICAL ENGINEERS,
QUEEN'S WHARF, HAMMERSMITH, W.
Undertake SPECIAL MACHINE WORK of any description.
WELL EQUIPPED SHOP.
LATHE WORK up to 10 ft. diameter.
'Phone: Hammersmith 31, 967. 9211

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John Kirkaldy, Ltd.,
London Office: 101, LEADENHALL ST., E.C.3.
Works: BURNT MILL, near HARLOW, ESSEX.
Makers of
Evaporating and Distilling Plants.
Refrigerating and Ice-making Machinery.
Feed Water Heaters.
Evaporators.
Fresh Water Distillers.
Main Feed Pumps.
Combined Circulating and Air Pumps.
Auxiliary Surface Condensers,
&c., &c. 1585

John Bellamy, Limited,
MILLWALL, LONDON, E. 1216
GENERAL CONSTRUCTIONAL ENGINEERS,
Boilers, Tanks, & Mooring Buoys
STILLS, PETROL TANKS, AIR RECEIVERS, STEEL CHIMNEYS, RIVETED STEAM AND VENTILATING PIPES, HOPPERS, SPECIAL WORK, REPAIRS OF ALL KINDS.

IRON & STEEL
Tubes AND Fittings AND Steel Plates.

STEWARTS AND LLOYDS, Ltd.
GLASGOW - BIRMINGHAM - LONDON.
See Advertisement, page 90. 1872

Peter Brotherhood Ltd.,
PETERBOROUGH.
STEAM ENGINES AND TURBINES.
GAS AND OIL ENGINES.
AIR COMPRESSORS.
REFRIGERATING PLANT. 1475
See Advertisement, page 53, Jan. 1.

The Glasgow Railway Engineering Company,
GOVAN, GLASGOW. LTD.,
London Office—12, Victoria Street, S.W.
MANUFACTURERS OF
RAILWAY CARRIAGE, WAGON & TRAMWAY WHEELS & AXLES.
CARRIAGE & WAGON IRONWORK, also CAST-STEEL AXLE BOXES. 1948

For Sale, Motor Generator, by
Lancashire Dynamo Co. Ltd., 1920, Comprising, 480 volt, D.C. Motor, coupled to 105 volt, 820 ampere compound interpole Generator, complete with Switchboard.
THE PHŒNIX ELECTRICAL CO., LTD., 17, Oswald Street, Glasgow. C 475

Castings:—Wanted, by
Modern Iron Foundry, WORK in the way of CASTINGS; orders from smallest sizes up to 10 tons.
Special Quotations for repetition work. Semi-steel Castings a speciality.
Highest quality, every satisfaction and prompt despatch.
Work for machine shop, also fitting, done if necessary. Well-equipped for repetition work on keen basis. Highest class workmanship, materials, etc. Prompt deliveries guaranteed. Estimates given.—Address, C 542, Offices of ENGINEERING.

Telegrams: "Epa," London.
Telephone: 7424 Central.
E. P. Alexander & Son.
CHARTERED PATENT AGENTS,
306, High Holborn, London, W.C. 1.
PATENTS. DESIGNS. TRADE MARKS.

For Sale, One 4-cyl. 300 HP.
National GAS ENGINE, coupled direct to compound Generator, 205 Kw., 110 volts, 300 r.p.m. Also PRODUCER GAS PLANT, suitable for above. The complete plant is in first-class working condition, and may be inspected at any time.
FODENS LIMITED,
Sandbach, Cheshire. C 744

For Sale:—
TWO 18 in. CENTRIFUGAL PUMPS, 20 in. Suction Pipes, 18 in. Delivery Pipes, direct coupled to Two "Reatler" Patent High Speed Engines, complete and in first-class order. Capacity of both Pumps, 20 million gallons per 24 hours to 40 ft. head.
JOHN JACKSON & CO. (IRON MERCHANTS), LTD., Balmoral Iron Yard, Scotstoun, Glasgow. C 739

Brazil.—Advertiser, long experience in Engineering and General Trades, shortly going to Brazil, would like to get in touch with firms desirous of supplying their manufactures. Would consider representing first-class firm.—Address, C 653, Offices of ENGINEERING.

Royles Limited,
ENGINEERS, IRLAM, MANCHESTER.
FEED WATER HEATERS,
CALORIFIERS, EVAPORATORS,
CONDENSERS, AIR HEATERS, } ROW'S PATENTS.
Merrill's Patent TWIN STRAINERS for Pump Suctions.
SYPHONIA STEAM TRAPS, REDUCING VALVES.
High-class GUNMETAL STEAM FITTINGS.
WATER SOFTENING and FILTERING. 5723

YARROW & CO. (1922), LTD., GLASGOW.
LAND AND MARINE
YARROW BOILERS. 1553

Matthew Paul & Co., Ltd.,
LEVENFORD WORKS, Dumbarton. 1483
See Full Page Advt., page 40, Feb. 1.

Forgings.
Walter Somers, Limited,
HALESOWEN. 7116

Taylor & Challen Presses
For Production of SHEET METAL WORK, COINAGE, CARTRIDGES AND GUNPOWDER.
Foundry, Works, and Showrooms: BIRMINGHAM.
See advert., page 63, Feb. 1. 8195

"Delta" Brand HIGH-CLASS ENGINEERING ALLOYS.
Forgings, Castings, Bars, Sheets, Wire, Tubes.
THE DELTA METAL CO., LTD., 1334
E. GREENWICH, LONDON, S.E. 10 (& at Birmingham)

Railway Switches and Crossings.
T. SUMMERSON & SONS, LIMITED, DARLINGTON. 1312

DAVID BROWN & SONS (Hudd.) Ltd.
Lockwood Huddersfield.
HIGH CLASS
Machine Cut Gearing
FOR EVERY PURPOSE. 1440

James D. Roots—Patents,
BRITISH and FOREIGN. Moderate charges, Long and varied practical Engineering experience valuable to Inventors. Formerly many years contributor of Patents Abstracts for "The Engineer" & "The Times."—Thanet House, Temple Bar, London, W.C.2.

For Your Repairs or any
SPECIAL MACHINERY, try
THOMAS HUNT & SONS,
Albion Ironworks,
Bridge Road West, Battersea, S.W. 11.
Est. 1854. 1792

To Rivet Makers.—A Firm of Tank Makers have orders to place with rivet makers outside the combine. Ring prices too high.—Address, C 703, Offices of ENGINEERING.

Gearing of all Descriptions,
SPUR WHEELS up to 10 ft. diameter.
FLY ROPE and SPUR DRIVING WHEELS up to 28 ft. diameter.
BRICK and CLAYWORKING MACHINERY of all kinds.
ENGINES:—"Uniflow," "Corliss," or Drop Valve.
CLAYTON, GOODFELLOW & CO., LTD., Blackburn. 1240

Centrifugals.
Pott, Cassels & Williamson,
MOTHERWELL, SCOTLAND. 1676
See half-page Advertisement, page 64, Jan. 18.

The Manchester Steam Users' ASSOCIATION.
For the prevention of Steam Boiler Explosions and for the attainment of Economy in the Application of Steam. 9, MOUNT STREET, MANCHESTER.
Chief Engineer: C. E. STROMEYER, M.I.C.E.
Founded 1854 by Sir WILLIAM FAIRBAIRN.
Certificates of Safety issued under the Factory and Workshops Act, 1901. Compensation for Damages and Liabilities paid in case of Explosions. Engines and Boilers inspected during construction. 1311

Correspondence Courses for Inst.Civil Engrs., Inst.Mech.E., London Univ. (Matric., Inter., B.Sc.), and All ENGINEERING EXAMINATIONS personally conducted by Mr. TREVOR W. PHILLIPS, B.Sc. (Honours), Assoc. M.Inst.C.E., M.R.S.I., F.R.S.A., etc., Also Day Tuition in Office. Excellent results at all Exams. Courses may commence at any time, and all Students receive individual tuition.—For full particulars apply to 8/11, TRAFFORD CHAMBERS, 58, SOUTH JOHN STREET, LIVERPOOL. 1295

Engineering Salesmanship and SALES MANAGEMENT.—Write for brochure describing our special Course of training for posts of unlimited scope in this lucrative field.—DIRECTOR, Institute of Engineering Salesmanship, 333, Oxford Road, Manchester. 1579

TENDERS.

SALE BY TENDER.

Tenders are Invited for the PURCHASE, DISMANTLING and REMOVAL of PLANT (Boilers, Electric Motors, etc.), lying at the Head Post Office, Liverpool.
Tenders will be received until Ten a.m., on Friday, the 15th February, 1924.
Forms of Tender, containing full particulars, can be obtained on application to the CONTROLLER, Post Office Stores Department (Accounts Section), Studd Street Depot, Islington, London, N. 1.
The Postmaster-General does not bind himself to accept the highest or any Tender.
By Order of the POSTMASTER-GENERAL.
General Post Office, February, 1924. C 839

SALE OF DISUSED STEAM-DRIVEN ELECTRICAL PLANT.

THE DUBLIN PORT AND DOCKS BOARD having obtained their Electric Power in Bulk, are open to consider

Tenders for their Disused STEAM GENERATING PLANT as standing at the Generating Station, Alexandra Basin.
The Plant consists of Three 200 Kw. and One 75 Kw., 500 V. D.C. Generators, with 15 Panel Switchboard, Booster and Balancer. The Generators are driven by Parsons Turbines, with usual auxiliaries; Three Babcock & Wilcox Boilers, fitted with Superheaters, Chain Grates, etc.
Offers for the whole or portion of the machinery will be entertained.
Full particulars and Order to View may be obtained from Engineer's Office, East Wall.
The Board do not bind themselves to accept the highest or any Tender.
Dublin Port and Docks Board, 5th February, 1924. C 869

MINISTRY OF TRANSPORT.

SURFACING OF ARTERIAL ROADS.

The Minister is prepared to receive

Tenders for Bituminous SURFACING in connection with certain sections of the Arterial Road known as Watling Street, Kent.
Specifications, Bills of Quantities, Forms and Conditions of Tender may be obtained from the Chief Engineer, Arterial Roads Department, Ministry of Transport, 7, Whitehall Gardens, S.W.1, upon payment of a deposit of £25.
This amount will be returned to the Tenderer if his Tender is a *bona fide* one, and has not been withdrawn prior to the definite acceptance of a Tender by the Minister.
The Drawings and Conditions of Contract may be inspected at the Ministry, and copies of the Specification, Bill of Quantities, etc., will be available on and after the 13th February, 1924
Tenders on the official form and accompanied by a fully priced Bill of Quantities must be submitted in a sealed envelope endorsed "Tender for Watling Street—Second Surfacing Contract."
The Minister does not bind himself to accept the lowest or any Tender.
Tenders must reach the undersigned by Ten a.m. on the 22nd day of February, 1924.
Dated this 6th day of February, 1924.
(Sd.) H. H. PIGGOTT, Assistant Secretary.
MINISTRY OF TRANSPORT. C 862

CITY OF HULL WATERWORKS.

DUNSWELL PUMPING STATION.

CONTRACT No. 5.

The Water and Gas Committee are prepared to receive

Tenders, from British Manufacturers, for the CONSTRUCTION and ERECTION of TWO SETS of PUMPING PLANT, each set capable of delivering Five Million Gallons of Water per 24 hours. The Plant to consist of Reciprocating Pumps driven by any Prime Mover—steam, gas, oil, electricity, etc.
Particulars may be obtained from the undersigned on a payment of a deposit of Five Pounds, which will be refunded on receipt of a *bona fide* Tender.
Sealed Tenders, endorsed "Pumping Plant," must be delivered not later than Ten a.m. on Wednesday, the 20th February, 1924.
By Order, C. B. NEWTON, M.Inst.C.E., Engineer.
Guildhall, Hull, 29th January, 1924. C 777

The Director General, India Store Department, Branch No. 16, Belvedere Road, Lambeth, S.E.1, REQUIRES:—
RAILS & FISHPLATES.
Tenders due on the 19th February, 1924.
Tender forms obtainable from above. C 861

TO STRUCTURAL ENGINEERS.

THE DUBLIN PORT AND DOCKS BOARD is prepared to receive

Tenders for the Supply of STEEL WORK for a Shed.
The material will consist of Columns, Girders, and Roof Trusses, amounting to about 40 tons weight.
Particulars can be obtained on application to the Engineer's Office, East Wall, between Ten a.m. and Four p.m.
Sealed Tenders, endorsed on outside "Shed Steel Work," should be delivered to the Secretary, Port and Docks Office, Westmoreland Street, not later than Eleven a.m. on Wednesday, 27th February, 1924.
The lowest or any Tender not necessarily accepted.
Port and Docks Office, 5th February, 1924. C 868

THE SOUTH INDIAN RAILWAY COMPANY, LIMITED, are prepared to receive

Tenders for the Supply of:—
1. 100 Four-wheel STEEL BALLAST WAGONS (M.G.)
2. Four Bogie PETROL TANK WAGONS (M.G.)
3. SCREWS.
4. BRUSHES.
5. LAMP FITTINGS and GLASSES.

Specifications and Forms of Tender will be available at the Company's Offices, 91, Petty France, Westminster, S.W.1.
Tenders addressed to the Chairman and Directors of the South Indian Railway Company, Limited, marked:—"Tender for Steel Ballast Wagons," or as the case may be, must be left with the undersigned not later than Twelve Noon, on Friday, the 22nd February, 1924, in respect of Specifications Nos. 3, 4 and 5, and not later than Twelve Noon on Friday, the 7 March 1924, in respect of Specifications Nos. 1 and 2.
The Directors do not bind themselves to accept the lowest or any Tender.
A charge, which will not be returned, will be made of:—
£1 for each copy of Specification, No. 1,
10/- " " " " " " 2 and 3,
5/- " " " " " " 4,
2/6 " " " " " " 5,
Copies of the drawings may be obtained at the Offices of Messrs. ROBERT WHITE & PARTNERS, Consulting Engineers to the Company, 3, Victoria Street, Westminster, S.W.1.
W. B. REYNOLDS, for Managing Director.
91, Petty France, S.W.1. 5th February, 1924. C 865

SALE BY TENDER.

Tenders are Invited for the PURCHASE of the following WAR DEPARTMENT PLANT at the CENTRAL ORDNANCE DEPOT, CHILWELL, NOTTS:—

(1) AN AERIAL ROPEWAY on the mono-cable system, approximately 1300 feet between stations, carried on 8 standards of varying heights, working at an average speed of 400 feet per minute and having a carrying capacity of about 60 tons per hour. There are 11 wooden buckets fitted with hanging brackets and rope grips, also one spare terminal wheel 7 feet diameter.

(2) A BRIDGE constructed of braced steel girders, with timbered floor, height 15 feet, length 40 feet, width 17 feet, used for carrying the above ropeway over a road.

Tenders should be addressed to:—
THE DIVISION OFFICER, R.E., Central Ordnance Depot, Chilwell, Notts.
The War Department does not bind itself to accept the highest, or any, Tender. C 820

BOROUGH OF HAMMERSMITH.

GENERAL ELECTRICITY STORES.

The BOROUGH COUNCIL invites

Tenders for the Supply of the following STORES for the period of 12 calendar months, commencing on the 1st April, 1924:—
1. Brooms and Brushes.
2. Electric Light Sundries.
3. Files.
4. Fire Bricks, Clay and Lime.
5. Insulated Wire.
6. Metals.
7. Oilman's Goods.
8. Steam Packing and Jointing Materials.
9. Tools.
10. Joint Boxes and Connections.
11. Meters (ordinary and prepayment).
12. Screws and Ironmongery.
13. Stoneware Conduit.
14. Insulating Compound.

Forms of Tender and further particulars may be obtained on application to Mr. G. G. BELL, Borough Electrical Engineer, 85, Fulham Palace Road, W.C., upon receipt of a stamped addressed brief envelope, and, where duplicate copies are required, a remittance of 2s. 6d. must be made.
Sealed Tenders, endorsed "Tender for Electricity Stores," must be delivered to the undersigned, at the Town Hall, Hammersmith, W.6, not later than Four p.m. on WEDNESDAY, 20th February, 1924. The Council does not bind itself to accept the lowest or any Tender. LESLIE GORDON, Town Clerk.
Town Hall, Hammersmith, W.6. 1st February, 1924. C 827

COUNTY BOROUGH OF HASTINGS.

ELECTRICAL DEPARTMENT.

The Electricity and Public Lighting Committee invite.

Tenders for the Supply, DELIVERY and ERECTION of all the PIPEWORK, VALVES, DEGASSER, TANKS, FEED PUMPS, and EVAPORATOR, required in connection with the new Electricity Works. Specifications and copies of drawings can be obtained from the Borough Electrical Engineer, 20, South Terrace, Hastings, on or before February 14th, on receipt of a crossed cheque for two guineas, which will be returned on receipt of a *bona fide* Tender.
Tenders, on prescribed forms, must be delivered to the undersigned not later than Noon, Thursday, February 28th, 1924.
D. W. JACKSON, Town Clerk.
Town Hall, Hastings, February 5th, 1924. C 857

WOOLWICH UNION.

Tenders are Invited to Supply and FIT a WEIGHBRIDGE, to carry up to twenty tons, at the Institution, Plumstead High Street.
A full Specification of the work must be submitted with the Tender.
For particulars of the site apply to the Master of the Institution.
The Guardians do not bind themselves to accept the lowest or any Tender.
Tenders must be sealed and endorsed "Tender for Weighbridge," and must be delivered at the Union Offices not later than the 13th instant.
By Order, ARTHUR HOLDER, Clerk to the Guardians.
Union Offices, Plumstead High Street, S.E. 18. 4th February, 1924. C 845

APPOINTMENTS OPEN.

Draughtsman Required for London with special experience of Gas-Fired Furnaces and Producers. Man with some knowledge of structural work and with workshop training and experience preferred. State age, experience and salary required.—Address, C 843, Offices of ENGINEERING.

DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH.

The Department requires the

Services of a Director of RESEARCH for Research into BUILDING MATERIALS and METHODS OF CONSTRUCTION.
Candidates should possess high general scientific qualifications with research experience and be capable of co-ordinating and controlling the work of a scientific staff. Importance will be attached to architectural-engineering experience.
The Department would be prepared to offer an inclusive salary not exceeding £1200 per annum to a suitably qualified candidate.
Applications, giving particulars of age, qualifications, war service, etc., and enclosing copies of testimonials and/or names of referees, should be made in writing not later than Saturday, March 1st, to the SECRETARY, DEPARTMENT of SCIENTIFIC and INDUSTRIAL RESEARCH, 16, Old Queen Street, S.W.1. C 838

ELY URBAN DISTRICT COUNCIL.

TO CONSULTING ENGINEERS.

The Ely Urban District Council propose to install a Plant for Generating Electricity for Lighting and Power Purposes and requires the

Services of a Consulting ENGINEER, to advise the Council on the most suitable Plant for the needs of the Council, the estimated cost of a complete installation, and on all matters relating to the Scheme generally.
Consulting Engineers prepared to advise the Council are requested to communicate with me, the undersigned, not later than Friday, the 15th day of February, 1924, giving particulars of their qualifications and the fee required.
Dated this 6th day of February, 1924.
A. K. CAMPBELL, Clerk to the Council.
Market Square, Ely. C 867

Manager Wanted for Engineering Works in the Midlands engaged on Colliery plant and constructional engineering work.
Must have had good experience in similar capacity preferably in similar works and be of proved abilities coupled with initiative and drawing office experience. Excellent scope for suitable man.
Replies, which should give fullest particulars of experiences and copies of testimonials or references, with salary required, to be addressed to C 852, Offices of ENGINEERING.

Applications are Invited for a VACANCY as SCIENTIFIC ASSISTANT in the Experimental Department of H.M. Signal School, Royal Naval Barracks, Portsmouth. The duties are concerned with the development of Receiving Apparatus for Wireless Telegraphy. Experience of W/T Reception is essential. Preference given to candidates possessing an Honours Degree in Physics and Research Experience.
2. The Salary is £250—20—450 plus Civil Service Bonus which at present increases £250 to £399 1 0. The Federated Universities' Superannuation Scheme is applicable.—Applications giving full particulars of the Candidate's experience, war service, etc. should be addressed to—THE SECRETARY OF THE ADMIRALTY (C.B.), Admiralty, S.W.1, not not later than 23rd February. C 770

Engineer to Take Charge of Stand at Wembley Exhibition:—"ENGINEERING," Friday, January 11th, 1924, No. C 853.—Advertisers wish to thank all applicants for the above post, which has now been filled. C 808

The Royal Air Force REQUIRES ELECTRICAL FITTERS, FITTERS ARRO ENGINE, FITTERS GENERAL, WIRELESS OPERATORS and POWER STATION TRADESMEN. Age limits:—Ex-Service men 18 to 30; Non Ex-Service 18 to 26; men highly skilled in certain trades up to 35; ex-N.C.Os. up to 38 (with rank according to trade ability). Pay from 24/6d. to 66/6d. per week, on enlistment, and all found. Allowance for wife and children to men 26 and over.—Write, stating age, or call:—
INSPECTOR OF RECRUITING, R.A.F., 4, Henrietta Street, Covent Garden, London, W.C 2. C 435

Wanted, Two First-class Men for Estimating and Ratefixing used to instrument work and toolmaking. Only those with a thorough practical experience and accustomed to laying out sequence of operations and speeds and feeds need apply. State age experience and salary required. —Address, C 823, Offices of ENGINEERING.

Young Engineer, Experienced in Estimating and Correspondence for oil engines, WANTED.—Address, stating age, experience and salary required. C 819, Offices of ENGINEERING.

Wanted, Experienced Auto- MOBILE MECHANIC, to take charge of Car Overhaul Shops.
Must have had wide general experience and be of good education. May be required to prepare estimates for complete overhauls and to interview Customers. Commencing salary £250.—Address, C 846, Offices of ENGINEERING.

SOUTH AFRICAN RAILWAYS & HARBOURS ADMINISTRATION.

Electrification of Glencoe-Maritzburg Section—Colenso Power Station.

The South African Railways & Harbours Administration require the

Services of Two Engineers to take charge of the operation of their power station at Colenso, containing 60,000 Kw. of plant, as (1) Resident Engineer; and (2) Combustion Engineer.
Applicants must have experience of the operation of large modern power stations and must be medically fit.—Apply, before 19th February, with copies only of testimonials, to Messrs. MERZ & MCLELLAN, 32, Victoria Street, Westminster, S.W.1; or to Messrs. MERZ & MCLELLAN, care of the GENERAL MANAGER, SOUTH AFRICAN RAILWAYS & HARBOURS ADMINISTRATION, Johannesburg, South Africa. C 841

Required, for South America, a CHARTERED CIVIL ENGINEER, to take charge under Chief Engineer of preparation plans and construction of large Terminal Station. Work will last several years. Applicants must have good experience of this class of work and not be less than 35 years of age.—Apply, with full particulars and stating salary required, to Box STATION, c/o DAVIES & Co., 95, Bishopsgate, E.C.2. C 875

Wanted, Senior Draughtsman. Aircraft experience desirable. Give full particulars and enclose references to the BLACKBURN AERO & MOTOR CO., LTD., Brough, East Yorks. C 751

Wanted, by Large Firm of Light-casting Manufacturers in Birmingham, Leading Jig and Tool DRAUGHTSMAN. Must be first-class man with knowledge of Modern shop practice. State age, experience and salary.—Address, C 816, Offices of ENGINEERING.

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VIBRATION AND STRUCTURAL DAMAGE.

By ERNEST LATHAM, M.Inst.C.E.

STRUCTURAL damage by vibration can arise from: (*a*) Natural earth tremors, earthquakes, &c.; (*b*) Vibration set up by surface traffic (railways and road vehicles); (*c*) Vibration caused by underground railways; (*d*) Vibration caused by machinery; (*e*) Settlement caused by periodic rise and fall of water in porous sub-soils; (*f*) Direct wave action on masonry, concrete, &c.; (*g*) Various combinations of the above; (*h*) By explosion.

It is the purpose of the present article to describe the physical results which may arise as the result of vibration transmitted by the operation of machinery and industrial plant. As, however, these results may either be primary or secondary causes of failure it is as well briefly to review the others, especially as the different effects may have to be separated in order to arrive at true conclusions. Mathematical data as to the nature, amplitude, periodicity and range of vibrations exist in many text books, and it is not the writer's intention to discuss this difficult and somewhat controversial aspect of the subject.

FIG. 1.

FIG. 2.

FIG. 3.

FIG. 4.

We have, then, the following considerations to bear in mind under the above headings.

(*a*) The effects of earth tremors in this country are slight, and little structural damage has been known to occur from this cause. No special precautions in the design of buildings are taken.

(*b*) The vibration set up by traffic on surface railways and roads has been the cause in certain cases of definite structural damage, resulting in actions in the High Courts. To differentiate such vibrations from those set up by factory machinery or other industrial plant seismographic records must be taken. The records taken in July, 1922, by Mr. Theodore W. Parkin on the site of the old Steam Packet Hotel in the City of London show the marked differences between the characteristics of graphs obtained from heavy road traffic and from adjacent pile-driving plant employing the McKeirnan-Terry type of steam hammer. It is doubtful, however, whether the use of the seismograph in vibration cases can be usefully employed as a measure of intensity, although its power of discriminating between different classes of vibration is undoubted. Where vibration has reached the extent where it becomes a "nuisance" in the eyes of the Law, the seismograph is too delicate an instrument to be trusted.

(*c*) Most of the so-called structural damage caused by the tube railways probably resulted more from their original construction than from the running of trains. It was recently stated in evidence by an eminent railway engineer that one street in London had been "narrowed" by ¼ in. owing to the two building lines on either side of the street coming towards each other as the result of piercing tube tunnels beneath and along the line of the street. One may well imagine this lateral movement to have been gradual, and any damage caused to buildings may wrongly have been attributed to the subsequent running of tube trains. The multiple-unit trains now used on nearly all tube railways have practically eliminated any "nuisance" of this character. The tubes generally pass under congested districts, and the vibration from motor 'buses, lorries and other vehicles have become the principal cause of urban traffic vibration. The writer had recently to report on a case in the West End of London where vibration was alleged and might have arisen from three possible sources:—

1. Factory machinery.
2. Underground railways.
3. Street traffic.

Of these three the last was undoubtedly the most insistent and marked. One point must be borne in mind in regard to traffic vibration where clay sub-soils are concerned. There is a marked difference in the range of disturbance (and, therefore, in the intensity of vibration at any particular point) between wet and dry periods, *i.e.*, vibration being more marked when the clay has a low water content than when saturated.

(*d*) It is more convenient to review this class of vibration after examining all other cases.

(*e*) The settlement of buildings resulting from a tidal pulse in the sub-soil below the foundations is by no means unknown; it is not a vibration in the ordinary sense, and is only referred to here in order that its effect may be looked for where the alleged cause of damage is not believed to be solely responsible for any failure. The settlement of buildings adjacent to pumping operations in an industrial area may also be wrongly attributed to adjacent vibration.

(*f*) Wave action on a sea wall or harbour pier produces a "shuddering" effect which can be very distinctly felt, and the vibrations set up in masonry and concrete travel a long way, following each wave stroke. Here again is a likely cause of damage to buildings adjacent to the sea which should not be overlooked where vibration from other causes is alleged.

(*g*) The most frequent combined vibration of a destructive nature is that arising from road traffic and machinery.

(*h*) The result of an explosion a few feet from the surface frequently sets up a violent earth tremor, and in cases of doubt as to the origin of cracks and fissures in buildings carrying or adjacent to machinery the possibility of an explosion having recently occurred in the neighbourhood should not

be ignored. The writer traced one such case in regard to a sea wall in Kent in the year 1920.

Having thus briefly reviewed and for the purpose of this article eliminated the various other causes which may arise and cause damage to structures, it is now possible to deal with the most common cause of failure under vibration, viz., that caused by industrial machinery and plant (*d*).

A valuable precedent is afforded in the case of May and Lavender decided in the Courts in the Autumn of 1911. This was a case where the plaintiffs (theatrical costumiers) alleged a nuisance to be caused by the vibration of the defendants' machinery through a 13½-in. brick party wall. The defendants were the printers and publishers of a musical review known as "The Strad," and had developed the back of some residential premises at Islington into a small printing establishment.

There was no doubt that *noise* was transmitted through the party wall in question, but there was considerable doubt as to the transmission of actual vibration. To differentiate between these two possible causes of a nuisance caused by one neighbour to another, was all important, because the neighbourhood was undoubtedly noisy from tram and other road traffic, but there were no other actual industrial undertakings adjacent or even very near to the plaintiff's premises. Lord Cave, the late Lord Chancellor, then practising as Counsel, undertook the defence in Court and successfully upheld his case.

The tests undertaken to disprove vibration were of a novel type. These took the form of "sand-cone" tests, and the photographs produced in the Court were ordered to be placed on record. Metal brackets were firmly fixed on the defendants' side of the party wall and supported glass plates in a horizontal position by means of set screws with the aid of which they were accurately levelled. On these glass plates little heaps or cones of fine dried sand were placed and the cones sprinkled with shell grit. A photograph was taken of the cone, and the printing plant then run under full load for a few minutes. A further photograph was then taken so that a comparison between the two photographs would show if vibration had caused any movement in the sand cone or displacement of the particles of shell grit. Figs. 1 and 2, on page 163, show the effect of violent vibration. In the first illustration a complete sand cone with the shell grit particles imposed thereon is shown. In the second both sand cone and shell grit particles have been completely displaced by vibration.

When this test was applied to the party wall in question quite different results were obtained, and as showing an average of several experiments Figs. 3 and 4 are given. These show no appreciable change, either in the shape of the sand cone or in the position of the shell grit particles. There is a difference in position of the light beams and shadows on the plates, but this was due to the interval of time which elapsed and the relative movement of the sun in its arc during that period. These photographs and the production in Court of certain component parts of the defendants' machinery enabled an injunction to stop an alleged nuisance to be successfully resisted.

The most useful case to the civil engineer engaged in this class of investigation is, however, that heard in November, 1922, by Mr. Justice Astbury in the Chancery Court. (Hoare *v.* McAlpine.) This case was of a special character, and its interest lies not so much in the nature of the claim as in the wealth of precedent quoted by the Judge in his summing up and by Counsel on both sides. The plaintiffs claimed that certain pile-driving operations in the vicinity undertaken for the purpose of securing foundations for a new building had caused the collapse of their adjacent premises (The Steam Packet Hotel, London Bridge). Their claim was upheld by the Court partly as the result of expert evidence and the production of seismograms, but principally as the result of effect and obvious cause.

The ruling of the Court in this case is also important, because in lay language it means that, "If a building has been constructed in accordance with the building laws and customs extant at the time of construction, no matter what its capacity of resistance to modern conditions may be, a loss resulting from any failure which may occur and can be satisfactorily traced to an adjacent and artificial cause is recoverable from the person creating such artificial cause."

This statement may well cause anxiety amongst builders, public works contractors and factory owners; it is not a verbatim extract from any legal or technical authority merely representing as it does the writer's conclusions from the observation of several alleged "nuisances" caused by machinery and industrial plant.

From the legal point of view vibration cases are not a class to themselves, but merely constitute a small section of the category known as "nuisance" cases, and engineers engaged in investigating the causes and results of machinery vibration require to acquaint themselves with all classes of precedent under the "nuisance" heading before they can be competent to advise. The following cases of this class are useful for reference :—

Case.	Nature.
Ryland and Fletcher, referred to in Hoare *v.* McAlpine 1922.	Flooding of an adjacent mining property by alleged unauthorised workings.
Attorney-General *v.* Cory Bros., 1921.	Landslide causing damage to adjacent property.
Eastern Telegraph Company *v* Capetown Tramways, 1902. Appeal.	Alleged interference with electrical apparatus by electrical current escaping to adjacent premises.
May *v* Lavender	Machinery vibration.
Hoare *v* McAlpine, 1922	Vibration caused by pile driving.

Other cases which have a bearing on the subject are National Telephone Company and Barber, Smith and Kenrick, Colwell and St. Pancras Borough (vibration), Walter and Selfe, Grosvenor Hotel and Hamilton, Robinson and Kilbert. Examination of these cases may suggest that some are in no way relevant to actions for damage by vibration, but in this respect a word of caution is necessary. It is not sufficient for the chartered civil engineer or other expert, if called upon to advise in such cases, to suggest that his advice must be confined to the purely physical aspect of the case. Any member of our profession will do himself a poor compliment in taking up this attitude because, if such a view is insisted on, one could not differentiate between possible nuisances which might be caused by the running of a sewing machine in a boiler shop or in a dwelling-house by the side of a sleeping baby.

COAL-GAS PLANT AT THE GREAT WESTERN RAILWAY WORKS, SWINDON.

A glance at the railway map of this country will show that the Great Western Railway system now covers a roughly triangular area, the apices of which are located at London, Birkenhead and Penzance. In this area the company owns or operates some 3,738 miles of line and employs for the purpose 3,940 locomotives, 10,181 coaching vehicles and 96,106 freight vehicles in addition to 53 rail motor cars. The construction of the locomotives, carriages and wagons, and the greater part of the maintenance and repair work for all kinds of rolling stock in the company's service are carried out at their works at Swindon in Wiltshire, and, this being the case, the figures mentioned above will enable a rough idea to be formed of the magnitude of the works, which were established in 1842. Actually about 1,000 locomotives, 6,000 carriages and 15,000 wagons, new and repaired, pass through the shops in the course of a year. The works occupy a total area of some 310 acres, of which 65 acres are roofed over, and employ about 14,000 hands, but it would not be very far from the truth to say that the whole of the inhabitants of Swindon, which has a population well exceeding 50,000, are either directly or indirectly dependent upon the railway works for their livelihoods.

Although much that is of very great interest to engineers might be said in connection with the plant and organisation of the works, we propose to confine our attention in this and in subsequent articles, to the description of a plant which has recently been installed there for supplying the works with coal gas for lighting and for use in the numerous gas-fired furnaces required for the heat treatment of steel and other heating processes. This plant, which was designed and constructed by Messrs. Robert Dempster and Sons, Limited, Elland, Yorkshire, consists of an installation of continuous vertical retorts on the Dempster-Toogood system, which are capable of carbonising 240 tons of coal and yielding about 3,000,000 cub. ft. of gas with a calorific value of 500 B.Th.U. per cubic foot, in a day. This capacity, it may be remarked, would be sufficient for the average requirements of a residential area containing some 100,000 inhabitants, and the plant is, in fact, the largest private installation of continuous vertical retorts in any part of the world. In addition to the carbonising plant, the installation includes elevators and conveyors for handling coal and coke, bunkers for storing both materials, screening and washing plant for coke, and a breeze-briquetting plant, as well as a gas-driven electric generating station which supplies the whole of the power required for operating the plant. A special feature of the design is that the plant has been laid out with a view to facilitating future extensions as far as possible. For this reason, the whole of the auxiliary plant is grouped at one end, leaving a free space at the opposite end, in which space it would be possible to erect a carbonising plant of equal capacity to that now in use without adding to the existing auxiliary plant. Another important feature of the design is that special attention has been given to the avoidance of any possibility of a shut-down. This has been accomplished by the duplication of all essential parts and the provision of change-over facilities so that, in emergency, each section can be employed for other duties than those upon which it is normally engaged.

Before commencing a detailed description of the new plant we should explain that the works were previously supplied by an installation of horizontal retorts put into service some thirty years ago and capable of supplying about 1,500,000 cub. ft. a day. The retorts were stoked by hand and charged by West's hand-scoop chargers, the coke being removed by hand-power rakes. The plant had become obsolete and was practically worn out, so that it was necessary for it either to be completely remodelled or replaced by an entirely new installation. The latter alternative was chosen after careful consideration, and the Dempster-Toogood system of carbonisation in vertical retorts was selected on account of its high efficiency and labour-saving characteristics. In this connection it may be mentioned that the old installation required 70 retort-house men for stoking, supplying coal and removing hot coke, whereas in the new plant these operations are carried out by mechanical means, which will be described later, so that only 24 men are required, although the gas production capacity has been doubled. The actual gas requirements of the works amount to an average of about 2,000,000 cub. ft. on an ordinary working day, although they occasionally reach 2,250,000 cub. ft. and naturally tend to increase. At present only two gasholders are available with capacities of 1,000,000 cub. ft. and 500,000 cub. ft., respectively, so that as the consumption during the week end falls to about 300,000 cub. ft., it is necessary to lay off some of the retorts towards the end of the week and start them up again on Sunday night. This can be done without difficulty, but to render the working conditions more uniform over the whole of the week, it has been decided to increase the storage capacity available and an order has been placed with Messrs. Dempster for the construction of a new holder with a capacity of 2,500,000 cub. ft., and work on this holder is now proceeding.

The carbonising plant and the coke-screening and washing plant are housed in two separate buildings placed end to end, with a small space between them. The building for the carbonising plant is 110 ft. long, 72 ft. wide and 73 ft. in height, while the dimensions of the building for the screening plant are length 80 ft., width 52 ft., and height 83 ft. Figs. 1 and 3, on pages 165 and 166, show the exterior of the buildings, Fig. 1 being taken from the screening-plant end and Fig. 3 from the carbonising-plant end. It will be seen from these illustrations that ample space is available for the duplication of the carbonising plant when necessary. Both buildings are steel-framed structures, and the structural work, as far as the buildings themselves are concerned, calls for no particular comment. It should, however, be pointed out that the walls are formed of 4½ in. brickwork filled in between the

CONTINUOUS VERTICAL RETORT COAL-GAS PLANT AT SWINDON.

CONSTRUCTED BY MESSRS. ROBERT DEMPSTER AND SONS, LIMITED, ENGINEERS, ELLAND, YORKSHIRE.

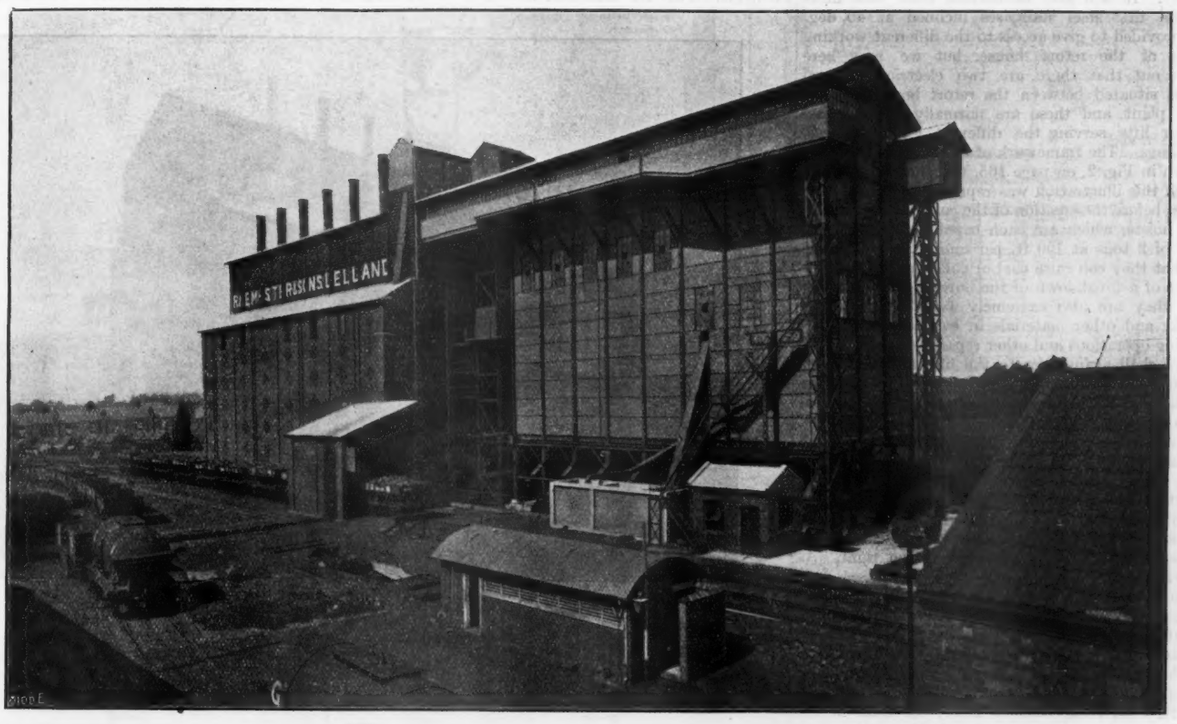


FIG. 1.

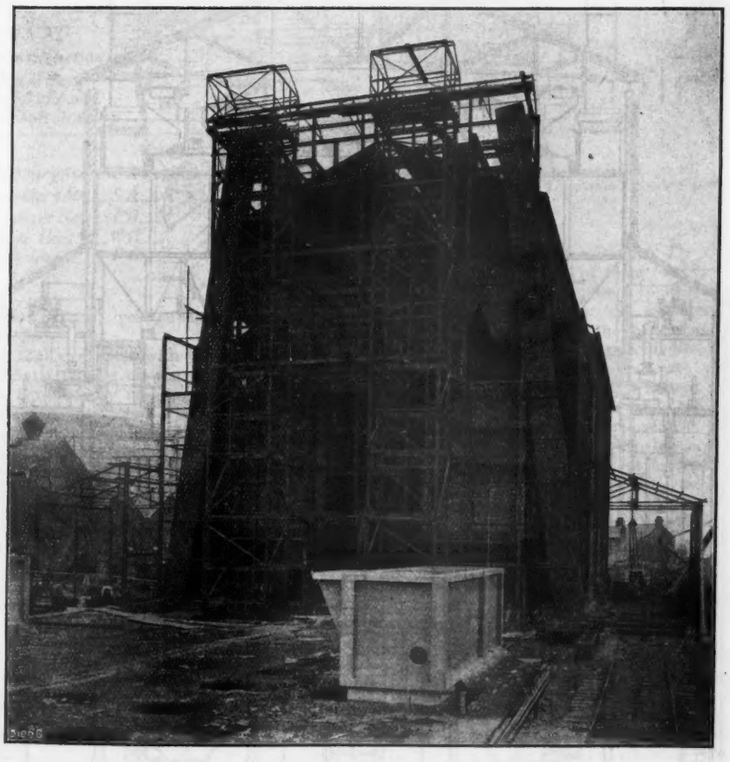


FIG. 2.

steel columns and reinforced with "T" bars built into the brickwork horizontally. These "T" bars are clearly visible in the coke-screening plant shown on the right of Fig. 1, and the arrangements are similar in the walls of the retort house, except that the reinforcing bars are there placed internally. This form of construction, we may mention, was first employed by Messrs. Dempster for the Cleethorpes Gas Works in 1909, and has proved very satisfactory for gas works buildings, being inexpensive, light and durable.

The general arrangements of the interiors of the retort-house and coke-plant buildings are well shown in the longitudinal section and plan, Figs. 5 and 7, on Plate IX, while that of the retort house is further illustrated by the transverse section, Fig. 4, on page 166, and the end elevation, Fig. 6, on Plate IX. The briquetting plant and power station are also shown on the right of the plan, Fig. 7. The retort house, with which we propose to deal first, contains twin benches built in parallel, each bench consisting of six standard beds of four retorts each, or 48 retorts in all; the overall length of the benches is 94 ft., and either can be worked quite independently of the other. A producer built into each bed supplies gas for heating the four retorts of that bed. The benches are supported on stout stanchions at a height of 13 ft. 6 in. above the ordinary ground level, this arrangement facilitating the removal of the coke and rendering the lower parts of the benches easily accessible. Each stanchion, of which there are four to each bed, supports a dead load of 115 tons, and is composed of two 10 in. by 6 in. rolled steel joists, connected by straps as indicated in Fig. 5. The stanchions are supported on a mass concrete foundation, 8 ft. deep, and, to prevent the possibility of any local settlement, two 15 in. by 6 in. rolled steel joists embedded in the concrete and running along the whole length of the building under each row of stanchions, were provided, as shown in Fig. 4. These embedded joists, it may be mentioned, greatly facilitate the work of erection, and also serve to distribute the load more uniformly over the concrete foundation. The bench brickwork is built up on a floor formed of steel joists with a capping of concrete, and to this floor are attached the columns which form the buckstays for the brickwork, and also carry the roof principals and the coal and coke bunkers mounted over the benches. Plate girder platforms are provided on the buckstays to brace the latter horizontally, and these are so

located relatively to the damper positions in the settings that they can be used as walking ways for controlling the heats. The transverse section, Fig. 4, annexed, shows the arrangement clearly. It will also be noticed from this illustration that steel staircases inclined at 45 deg. are provided to give access to the different working levels of the retort house, but we may here point out that there are two electrically-driven hoists situated between the retort house and the coke plant, and these are normally used as passenger lifts serving the different levels of both buildings. The framework of these hoists is clearly shown in Fig. 2, on page 165, the photograph from which this illustration was reproduced having been taken before the erection of the coke-plant building. The hoists, which are each capable of handling a load of 2 tons at 100 ft. per minute, are arranged so that they can raise coal or coke in trucks in the event of a breakdown of the normal arrangements, and they are also extremely useful for handling bricks and other materials in connection with resetting operations and other repair work.

We shall again refer to the lifts and their uses when describing the coal and coke-handling appliances, but, before doing so, we propose to deal with the carbonisation plant, since this is, of course, the most essential feature of the installation. The transverse section of the retort house given in Fig. 4, on page 165, illustrates the general arrangement of the retorts and their settings, one of the retorts and a group of heating flues being shown in section on the left of the illustration, while a section through the producer is given on the right. As previously mentioned, each bed comprises four retorts and one producer, two retorts being placed on each side of the producer which is built into the front part of the setting while the chimney for the waste gases is situated at the back. The dimensions of the brickwork settings of each bed are 23 ft. 9 in. from top to bottom, 15 ft. from side to side, and 17 ft. 4 in. from back to front. Sections of the retort, to a larger scale, are given in Figs. 8, 9 and 10, on page 167, and from the horizontal section, Fig. 10, it will be seen that the retort proper is built up of specially shaped refractory bricks. The section tapers from the top downwards, rapidly at first and then more gradually, the increase in sectional area preventing the charge from sticking as it swells in the process of carbonisation. The retorts measure 40 in. by 8 in. at the top and 60 in. by 20 in. at the bottom, and their length is 23 ft. 6 in.

Each retort is heated by four gas flames on both sides, the burners being situated near the upper end and the hot gases travelling downwards through separate flues which follow the sides of the tapering retort as shown in Fig. 9. The green coal, as it enters the retort, is first subjected to a temperature of about 700 deg. C. from the waste heat on its way to the chimney, which serves to dry and prepare the coal and to drive off some of the more volatile constituents. As it descends, the temperature rapidly increases and the coal nearest to the retort walls is carbonised. The maximum temperature, of 1,400 deg. C., is reached at about one-third of the distance from the upper end, carbonisation extending radially inwards, as indicated in Figs. 8 and 9, until the coal has travelled downwards for about half the length of the retort, by which time the carbonisation process has been completed. It should be pointed out, however, that the carbonisation takes place in an atmosphere of hydrogen produced from the water gas generated by steam admitted at the bottom of the retort travelling upwards through the incandescent coke. The hydrogen gases have the effect not only of facilitating the removal of the gas from the coal during carbonisation, but they also enter the interstices of the coke and assist the release of any imprisoned volatiles it may still contain. Steam, we should mention, is admitted in the saturated state at the bottom of the retort through the pipe lettered S_1, in Fig. 8, and the quantity supplied is that which passes through a $\frac{1}{4}$-in. orifice at a pressure of 30 lb. per square inch. The steam superheating device illustrated on the right of Fig. 8 is sometimes fitted, but is more suitable for use when gas of a low calorific value is required. It is not actually fitted at Swindon, where the gas made has a calorific value

COAL-GAS PLANT AT SWINDON.

CONSTRUCTED BY MESSRS. ROBERT DEMPSTER AND SONS, LTD., ENGINEERS, YORKSHIRE.

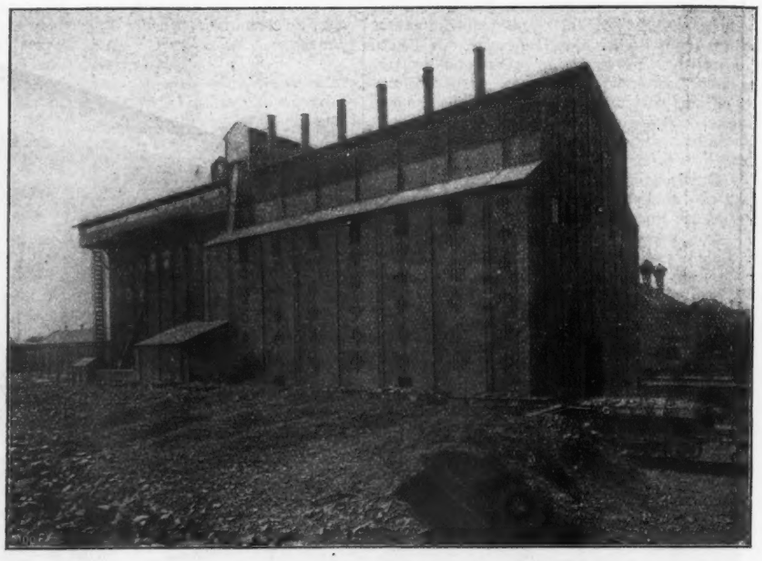
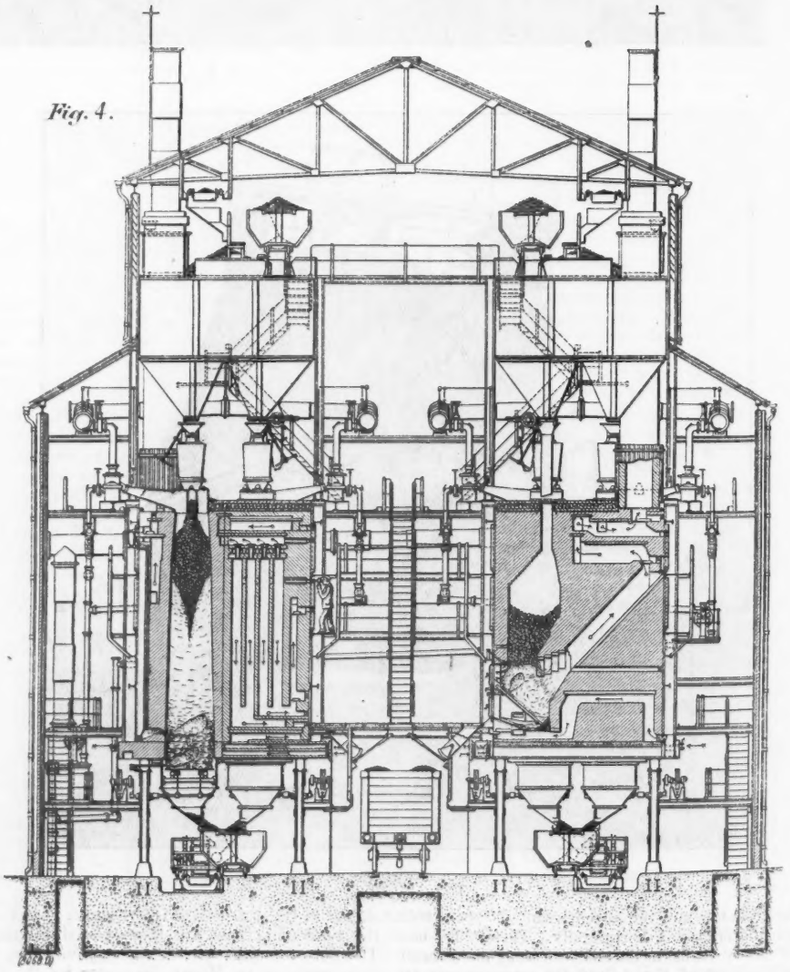


Fig. 3.

Fig. 4.



CONTINUOUS VERTICAL RETORT COAL-GAS PLANT AT SWINDON.

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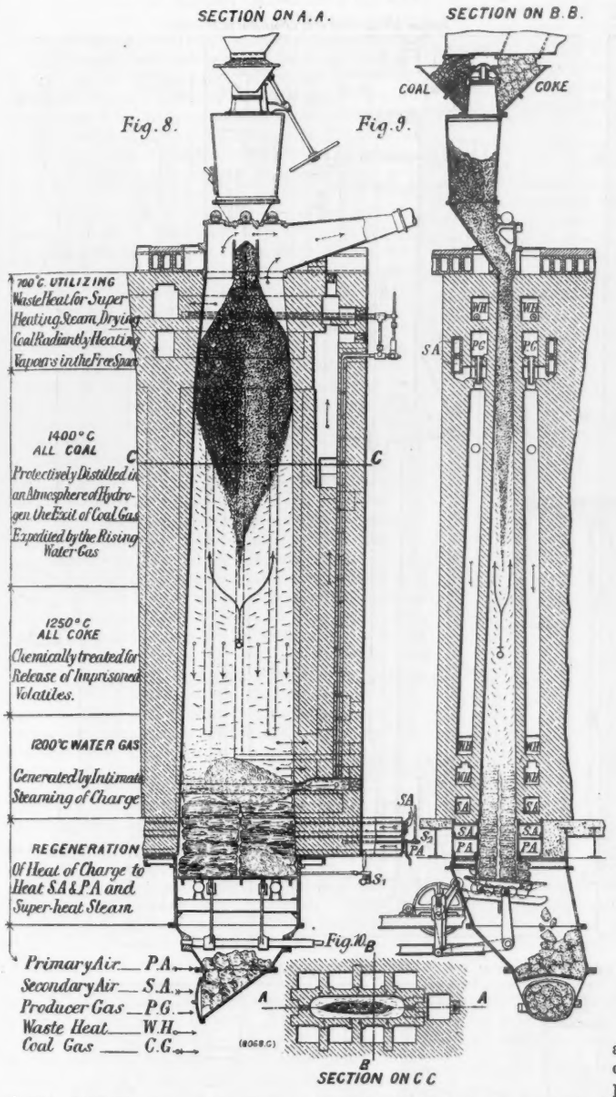
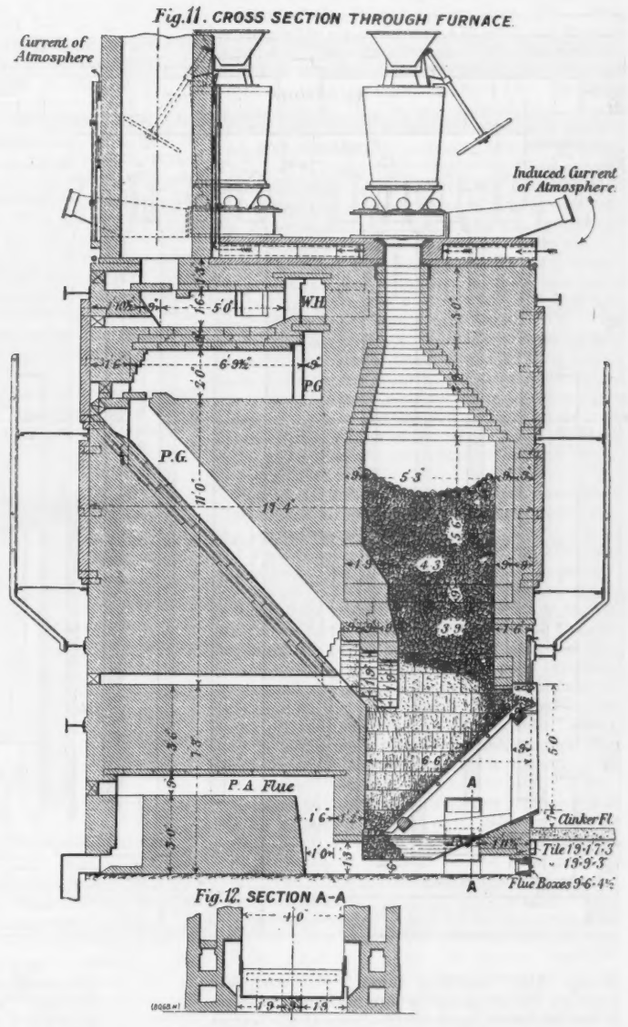

SECTION ON A.A.
SECTION ON B.B.
Fig. 8.
Fig. 9.
COAL
COKE
700°C. UTILIZING
Waste Heat for Super Heating Steam, Drying Coal Radiantly Heating Vapours in the Free Space
1400°C ALL COAL
Protectively Distilled in an Atmosphere of Hydrogen the Exit of Coal Gas Expedited by the Rising Water Gas
1250°C ALL COKE
Chemically treated for Release of Imprisoned Volatiles.
1200°C WATER GAS
Generated by Intimate Steaming of Charge
REGENERATION
Of Heat of Charge to Heat S.A. & P.A. and Super-heat Steam
Primary Air P.A.
Secondary Air S.A.
Producer Gas P.G.
Waste Heat W.H.
Coal Gas C.G.
Fig. 10.
SECTION ON C C



of 500 B.Th.U. per cubic foot, as previously mentioned.

We shall deal later with the method of charging the retorts, taking off the gas and extracting the coke, but we may now explain that the latter is supported at the bottom of the retort on a reciprocating plate, from the side of which it gradually falls into a closed hopper. The heat of the coke is utilised to raise the temperature of the supply of primary air to the producer and the secondary air to the burners heating the retorts. In this way the coke is cooled so effectively that there is no possibility of its igniting after removal; it can, in fact, be held in the hand immediately after its removal from the hopper.

The section of the producer reproduced in Fig. 11, annexed, shows its design and construction very clearly. The producer has an elliptical body, a half-section of which is shown in the bottom right-hand corner of Fig. 17, on page 168. The upper part of the producer body is tapered as shown in Fig. 11, and coke is supplied to it through an inlet at the top by means which will be described later when dealing with the method of charging the retorts. The grate is composed of fixed bars inclined at 45 deg., as shown in the illustration, and these bars are made in the form of troughs down which water is allowed to trickle into the closed ash pit. The evaporation of some of this water supplies a considerable part of the steam required for the producer, and the water, of course, keeps the bars quite cool and thus greatly increases their useful life. The back and side walls of the furnace are vertical, so that clinkers will not readily adhere and, owing to the steeply-inclined fire-bars, the movement of the fire, as the fuel is consumed, allows the ashes to fall freely towards the back of the grate, whence they are raked out at intervals of about 4 hours. The ashes contain little or no unburnt coke, the quantity being insufficient to justify washing. No trouble is experienced with clinkers, and we understand that one of the furnaces has been in use at Swindon for fifteen months continuously without clinkering. Actually only three grates of the type illustrated are installed at present, the remainder being of the step type; but these are being replaced as opportunities occur.

The primary air, with the remainder of the steam required for the producer, first enters through four passages formed by steel plates and running along on each side of the retorts at the bottom. Two of these passages are indicated by the letters P.A. in Fig. 9, and the pipe through which the steam is delivered is lettered S_2, in Fig. 8. A connection from these passages, shown in the bottom left-hand corner of Fig. 11, leads the air and steam into a flue formed in the brickwork setting and the mixture is delivered into the ashpit on both sides through cast-iron ducts set in the brickwork. The primary air flue is clearly shown in Fig. 11, and Fig. 12 shows the connections to the ash pit. It is, perhaps, hardly necessary to point out that the supply of an evenly saturated homogeneous mixture in this way over the whole of the grate area, avoids any local cooling or heating effects on the fire and results in more uniform working than is obtained with concentrated jets.

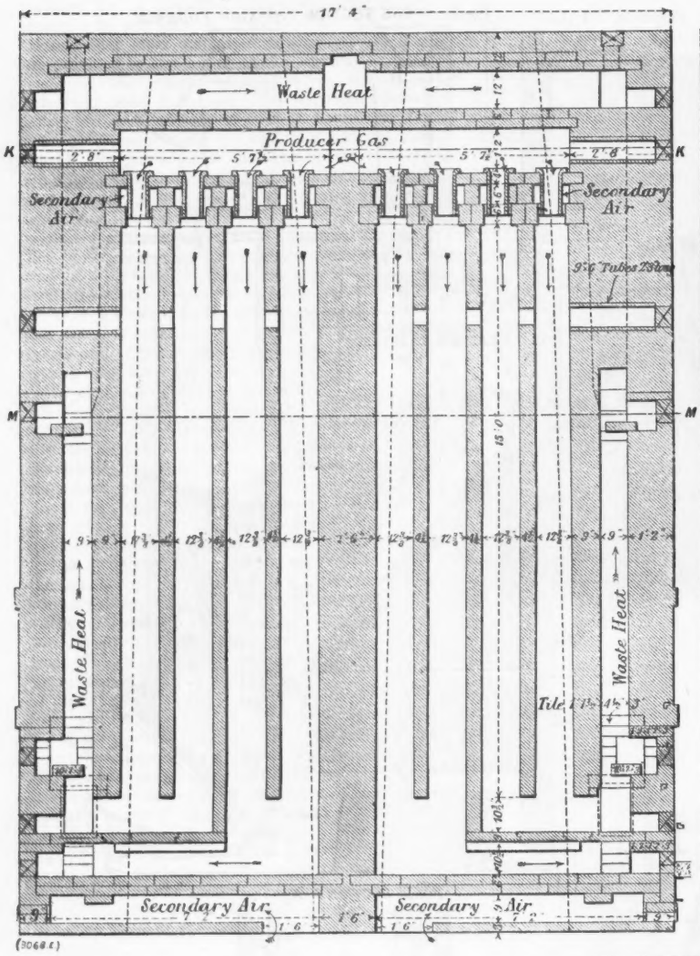
The gas leaves the producer through a flue lettered P.G. in Fig. 11, and this flue, it will be noticed, is inclined at 45 deg., so that any dust deposited in it slips back into the fire, thus avoiding any fluxing action on the more highly-heated refractories in the combustion chambers. The gas then travels forwards through two horizontal flues to the centre of the setting, each flue supplying the burners of two retorts as will be clear from an inspection of Fig. 16, on page 168.

The secondary air for the combustion of the producer gas at the burners, enters the system through steel plate passages at the bottom of the retorts just above the primary air entrance passages, and lettered S.A. in Fig. 9. External screw slides on the inlets enable the quantity of air entering to be adjusted independently for each side of each retort. The main object of the air regulators is, of course, to enable the correct combustion conditions to be maintained, but a certain amount of temperature control can be effected by this

CONTINUOUS VERTICAL RETORT COAL-GAS PLANT AT SWINDON.

CONSTRUCTED BY MESSRS. ROBERT DEMPSTER AND SONS, LIMITED, ENGINEERS, ELLAND, YORKSHIRE.

Fig 13. SECTION ON B. B.



(3068 E)

Fig. 14. SECTION ON E. E.

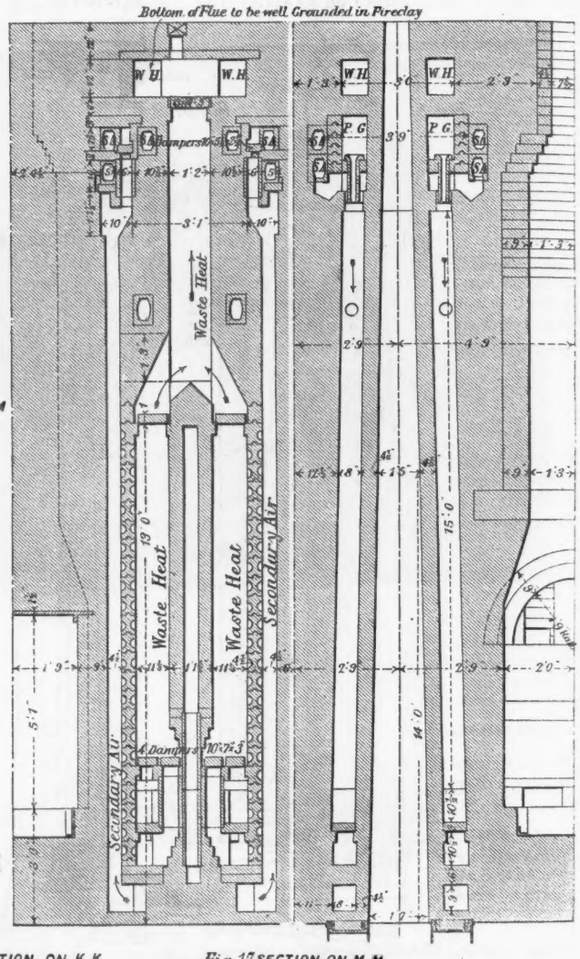
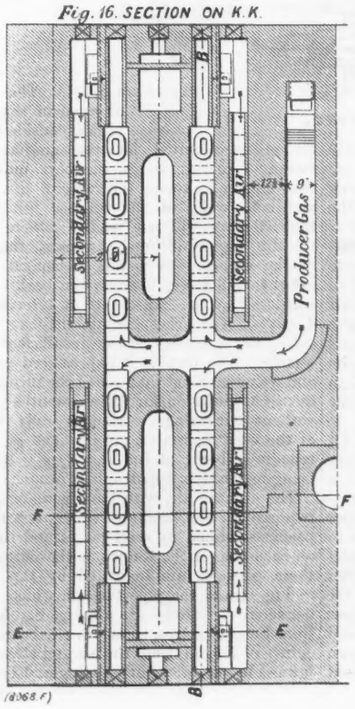


Fig. 15. SECTION ON F. F.

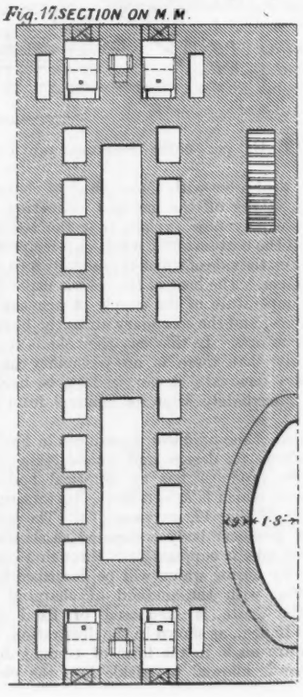
means. After travelling through the steel-plate passages, the air passes up into horizontal passages in the brickwork, most clearly shown at the bottom of Fig. 13, annexed, and then travels upwards through vertical passages on each side of the waste-heat flues, as shown in Fig. 14. The partition between the waste-heat flues and the secondary-air passages is 4½ in. thick, with panels only 1½ in. thick, and is formed of specially shaped bricks which facilitate the transmission of heat so that the temperature of the air is raised to about 800 deg. C. At the top of the setting, the vertical passages are connected to horizontal passages best shown in Fig. 16, and these lead the air to the spaces surrounding the burner nozzles, as will be clear from an inspection of Fig. 15. The flame and hot gases resulting from the combustion of the producer gas travel downwards through four flues on two sides of each retort. At the bottom of the setting, the four flues on each side of a retort are combined into two horizontal passages as shown in Fig. 13, and these, in turn, are connected to a single ascending passage which thus takes the whole of the products of combustion from the four flues on one side of a retort. About halfway up, this passage combines with a similar passage leading from the other side of the same retort, as shown in Fig. 14, and the gases finally escape to the chimney after passing through the horizontal waste-heat ducts at the top of the setting. As previously mentioned, the horizontal waste-heat ducts pass on each side of the retorts, and some of the heat in the gases is utilised for the preliminary heating of the coal in the retorts. We should also mention,

Fig. 16. SECTION ON K. K.



(3068 F)

Fig. 17. SECTION ON M. M.



although this will have been noticed in the illustrations, that dampers are provided at intervals in the waste-heat flues to enable the temperature to be controlled. The lower dampers each control two of the vertical descending flues on one side of a retort, the central dampers each control the four flues on one side of the retort, and the top damper controls the whole of the eight flues simultaneously; the last-mentioned damper can thus be used for regulating the temperature of the retort as a whole, while the others can be used for local temperature adjustments. The dampers actually consist of firebrick blocks, which are moved horizontally by means of iron rods inserted through plugged holes in the setting.

Before leaving the settings we should refer to a particularly interesting feature of the design, which has been adopted for the purpose of keeping the bench tops cool. The bench tops, of course, form a working floor upon which the stoker spends a considerable part of his time charging the retorts and producers, poking the charge in the retorts at intervals and carrying out any operations which may be necessary in connection with the delivery of the gas to the foul main. In the ordinary way the position would be rendered distinctly uncomfortable by the heat from the brickwork, but this difficulty has been completely overcome by the simple expedient of constructing the working floor of hollow bricks through which a current of atmospheric air is induced. The arrangements are illustrated in Figs. 8, 9 and 11, the latter illustration showing the simple method adopted for inducing the flow of air. For this purpose, the brickwork of the chimney, which is cylindrical, is surrounded for a height of 6 ft. above the bench-top level by two layers of corrugated asbestos sheeting spaced about 2 in. apart, and the hollow vertical spaces between the sheets are open to the atmosphere at their upper ends and are connected at the bottom to the horizontal channels formed by the hollow bricks, so that, as the heated air in the spaces between the sheets rises and escapes into the atmosphere, it is replaced by cool air drawn in through the hollow bricks, the channels in which are opened to the atmosphere at one end, as indicated in Fig. 11. The asbestos sheets also prevent the heat radiated from the chimney from reaching the workers on the bench top, so that they can carry on their duties under conditions which compare very favourably with those existing in an ordinary retort house employing horizontal retorts.

Another point which should be mentioned in connection with the retort settings, is that, in order to reduce heat losses to a minimum, the upper parts of the sides are covered with a 4½ in. layer of special insulating bricks which are clearly shown in Fig. 11. These bricks are only applied after the settings have been built and thoroughly heated up and all visible cracks have been closed by pointing. They are then built on while the setting is hot, headers being left protruding at intervals from the settings as first constructed in order to provide a bond for the insulating bricks. The effectiveness of the latter is indicated by the fact that the hand can be held on them comfortably while the headers of ordinary firebrick can hardly be touched.

This feature doubtless contributes to the comfort of the workers in the retort house, which is remarkably cool and airy. From the external views of the building reproduced in Figs. 1 and 2, on page 165, it will be noticed that the brickwork side and end walls are formed with numerous perforations and that pivoted windows are provided all round at the bench top level. A platform extending all round the building enables these windows to be opened and cleaned from the inside. Above the windows the sides of the buildings are formed of louvres, and the roof itself is open for a width of 2 ft. 6 in. along the centre line. This opening not only provides an effective exit for the escape of hot air, but also gives a good light for the whole of the interior down to the floor at the level of the producer ash pits.

(To be continued.)

AMERICAN AGRICULTURAL IMPLEMENTS.—According to *Iron Trade Review*, Cleveland, Ohio, exports of agricultural implements from the United States in November gained in value by more than 500,000 dols. over the October exports, the figures being 3,807,223 dols. in November, and 3,224,780 dols. in October.

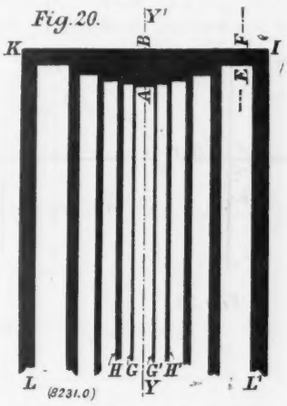
THE ELEMENTS OF THE LANCHESTER-PRANDTL THEORY OF AEROPLANE LIFT AND DRAG.

(Continued from page 102).

So far, aeroplane wings of infinite aspect ratio have alone been considered, but actual wings are necessarily of limited span and the average lift per unit length is less than it otherwise would be. At the top of the wing (see Fig. 13, page 100 *ante*) the stream-lines are crowded together, and this implies that in this region the speed of the air is high. But by Bernoulli's theorem, where the speed is high the pressure must be low, or in other words a partial vacuum exists at the upper surface of the wing, and this is a maximum at the axis of symmetry and vanishes at the wing tips. This difference between the pressure at the tips and the pressure at the middle of the wing gives rise to a flow of air at right angles to the direction of flight so that with actual wings the motion of the air has a transverse component as well as a fore and aft one. Hence the vortex lines formed by the surface friction are no longer parallel to the transverse axis of the machine but are curved.

A vortex line may be regarded as a "materialised spin," and a spin can be represented by a vector and resolved into components just as if it were a

Fig. 20.



force or a velocity. Hence each elementary length Δl, say, of the curved vortex lines, met with in the case of actual wings, can be resolved into component vortex lines Δx and Δy respectively, where Δx represents the component transverse to the direction of flight and Δy the component parallel to the axis of flight. The former alone produces circulation round the wing and thus contributes to the lift. Hence if the circulation around the curved vortex line was Γ_l, per cm. run, the transverse component, which alone contributes to the lift will be $\Gamma_l \frac{dx}{dl}$ per cm. of the wing length. The "lift" circulation therefore diminishes from the centre of the wing to the tips where it is zero.

The general character of the vortex system associated with an actual wing is very roughly represented in Fig. 20 This model, crude as it is, has led to the establishment of a reliable law of comparison between wings of different aspect ratios, and has provided the means for determining how one wing of a biplane interferes with the other and has also shown that wind tunnel experiments require a correction to reduce them to free air conditions. In this model the wing is replaced by a bundle of vortex lines. This bundle is thickest at the centre, and successive lines are turned off at right angles as we proceed from the centre to the tip. The turned-off portions all lie in the plane of flight. In Fig. 20 KI represents the span of the wing, the axis of symmetry of which lies along the line YY'. The circulation round the bundle at any point is intended to be represented by the thickness. This for example, is AB at the centre line and EF further out.

In the case of a real wing, the vortex lines at the centre are all parallel to KI, and the circulation here is proportional to AB. At a little distance from YY' however, the vortex lines are no longer parallel to KI, but being curved, have a small component parallel to YY'. The corresponding loss of "lift" circulation is represented in Fig. 20, by turning off at right angles some of the vortex lines as indicated by GG'. A little later on the inclination of the real lines associated with the wing is still more pronounced, and the component parallel to YY' is still greater, and this is represented in the figure by turning off the thicker trailing lines HH'. Proceeding in the same way we get stronger and stronger bundles of vortex lines turned off until finally at the wing tips the whole of the remaining lines are turned off to form the trailing vortex lines LL'. The wing is therefore, on this model, replaced by a system of transverse vortex lines and a system of trailing vortex lines extending to infinity behind the plane. The whole of these vortex lines are regarded as lying in the one plane. Were the plane of infinite aspect ratio, these trailing vortex lines would not exist, and the thickness of the bundle responsible for the lift would be the same from end to end of the span.

Actually the "lift" circulation is a maximum at the centre and zero at the tips, so that the average lift per centimetre run is very materially less than that with a plane of infinite aspect ratio. The drawbacks associated with a finite aspect ratio do not, however, end here. Each of the trailing vortex lines shown in the diagram, is surrounded by its own system of circulation and thus tends to produce a flow of air past the line K I and adding the individual effects of each of the whole series the result is the production of a downward velocity of the air at every point of K I.

Now in the first article it was shown (see page 2 *ante*) that if air streamed past a fixed vortex line, the result was that the pressure on one side of the vortex line was increased and on the other diminished. We thus found that the lift per unit length was equal to $\rho V \Gamma$, where V denoted the velocity of flight, Γ the strength of the circulation at the element considered and ρ the density of the air. Applying this result here it will be seen, that if w be the downward velocity at any point, produced by the trailing vortices as above explained, there will be a drag on the wing which will be equal to $\rho w \Gamma$ dynes per centimetre run. This induced "drag" may be much more than the surface friction drag which is alone encountered, when the wing has infinite aspect ratio.

Each of the trailing vortex lines represented in Fig. 20 tends to make each of its fellows move with the same velocity as the vortex line would give to a similarly situated filament of the fluid were no other vortex present. In other words if two parallel vortex lines having the same direction of spin exist in a fluid each tends to make the other move at right angles to a line joining the two, and the pair thus revolve round each other. It follows, therefore, that all the trailing vortex lines shown to the left of YY' wind round each other into a helix, but as the outermost line KL is far the strongest, this means that in practice all the others wind round it, thus producing a Lanchester "tip vortex." Similarly all the trailing vortex lines to the right of YY' wind round the line IL' at the right hand tip.

This pair of "tip vortices" moves downward under their mutual interaction. In calculating the downward velocity w which these trailing vortices produce past the lift vortex line KI (Fig. 20), these secondary effects are neglected, and it is assumed that in some way or other the lines in the system shown are constrained to remain parallel to each other and that they extend to infinity behind the wing. If this system of vortex lines also extended to infinity in front of the wing each might be regarded as the core of a Rankine vortex. Now on page 2 *ante* it was shown that the velocity which a Rankine vortex imparts to a particle of fluid, situated at a distance of r cm. from it, is $\frac{\gamma}{2\pi} \cdot \frac{1}{r}$ where γ denotes the circulation per centimetre run characteristic of the vortex line in question. Thus if in Fig. 21 the trailing vortex line represented by cd extended also in front of KI as indicated by the dotted line, the speed it would give to a particle of fluid situated at B would be $\frac{\gamma}{2\pi} \cdot \frac{1}{x-k}$ Since, however, the trailing vortex line exists only on one side of KI the velocity imparted will be half this or $\frac{\gamma}{4\pi} \cdot \frac{1}{x-k}$.

If we take into account the individual effects of

each of the system of trailing vortex lines the resultant velocity at B will be the algebraical sum of the velocity due to each.

In Fig. 20 the trailing vortex lines have been represented as coming away from KI at certain isolated points, but actually of course they leave continuously all along the line KI constituting a continuous sheet of trailing vortex lines. If we plotted the actual circulation along KI we should get in fact a continuous curve such as KMI, Fig. 22, and not the stepped form indicated in Fig. 20. The important point to note is that the whole of the "lift" circulation lost along KI as we go from the centre line outwards is gained by the trailing vortices. Hence if γ denotes the circulation per centimetre of the trailing vortex line at any element of length Δk situated k centimetres from YY^1 then γ is equal to the lift circulation lost in the distance Δk whence

$$\gamma = \Delta\Gamma = \frac{\partial\Gamma}{\partial k} \cdot \Delta k.$$

Thus this vortex line will produce a downward velocity (perpendicular to the plane of the paper) at any point x of the line KI equal to

$$\frac{1}{4\pi} \cdot \frac{\partial\Gamma}{\partial k} \cdot \frac{\Delta k}{x-k}$$

The total downward velocity at x is therefore found by integrating this expression

That is

$$w = \frac{1}{4\pi} \int_{-a}^{+a} \frac{\partial\Gamma}{\partial k} \cdot \frac{dk}{x-k}$$

Now as shown above, the drag produced on a length Δx of the line KI is equal to $\rho\, w\, \Gamma\, \Delta x$.
Hence the total "induced drag" W is given by

$$W = \rho \int_{-a}^{+a} w\Gamma\, dx = \frac{\rho}{4\pi} \int_{-a}^{+a} \Gamma \cdot dx \int_{-a}^{+a} \frac{\partial\Gamma}{\partial k} \cdot \frac{dk}{x-k}.$$

The value of this can be calculated if Γ is known, though certain difficulties do arise from the circumstance that $\frac{1}{x-k}$ passes from $+\infty$ to $-\infty$ as k passes through the value x. Disregarding these for the present it is obviously of interest to ascertain what is the least total induced drag obtainable with a specified total lift. It turns out that this induced drag is least when w is constant from end to end of the wing span.

The proof of this proposition is easily obtained by the calculus of variations.

Consider for example any little element Δk of the span situated at a distance k from YY^1 (Fig. 22). Then each particle of air as it passes this element is given a downward velocity w and acquires a kinetic energy proportional to w^2. If V be the velocity of flight the number of air particles passing Δk per second will be proportional to $V\,\Delta k$. Hence the total kinetic energy produced by the trailing votices will be proportional to $V\int_{-a}^{+a} w^2\, dk$. This energy is represented by the work done against the induced drag. Hence we may write

$$V\int_{-a}^{+a} w^2\, dk = \text{C.V.W.}$$

Where C is some constant coefficient of which it is unnecessary for our argument to know the numerical value. But $W = \rho\int_{-a}^{+a} w\Gamma\, dk$.

Hence we may write

$$\int_{-a}^{+a} w^2\, dk = B\int_{-a}^{+a} w\Gamma\, dk. \quad . \quad . \quad \text{(H)}$$

Where B is some other constant coefficient. Now for minimum drag, the work wasted in this "downward" kinetic energy must be a minimum, but this is subject to the condition that the lift shall have a specified value which we may denote by A.

The value of A is of course given by the expression

$$A = \rho V \int_{-a}^{+a} \Gamma\, dk$$

If next we differentiate both sides of equation (H) with respect to w we get

$$2\int_{-a}^{+a} w\, dk = B\int_{-a}^{+a} \Gamma\, dk$$

But the right hand side is, it will be seen, proportional to A. We thus see that if the lift is to be fixed we must have $\int_{-a}^{+a} w\, dk = \text{constant}$.

Calling this constant λ we have then to make $\int_{-a}^{+a} w^2\, dk$ a minimum subject to the condition that

$$\int_{-a}^{+a} w\, dk - \lambda = 0.$$

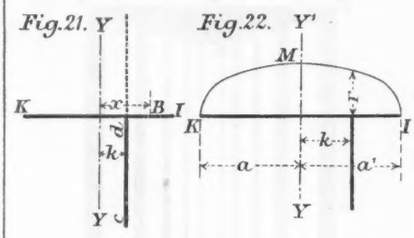
Hence, by the usual rules, we multiply this last expression by an arbitrary constant m say, and add it to the integral which is to be made a minimum. This done we make the resultant integral a minimum. We then get

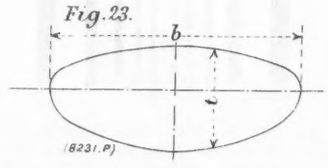
$$\int_{-a}^{+a} [w^2 + m\, w]\, dk - m\lambda = \text{a minimum.}$$

By the usual rules of the calculus of variations this gives us

$$2w + m = 0$$

But m is a constant, therefore w = constant is





the condition for minimum drag when the total lift is specified.

It is possible by numerical calculation to determine approximately the form of the "circulation" curve (KMI Fig. 22), which will make w a constant, and it turns out to be elliptical in character.

We shall assume therefore that the circulation at any point of the wing is given by the relation $\Gamma = \frac{\Gamma_0}{a}\sqrt{a^2-x^2}$ where x denotes distance from YY^1 and Γ_0 is the circulation at mid-span.

The total lift becomes then

$$A = \frac{\rho\, V\, \Gamma_0}{a} \int_{-a}^{+a} \sqrt{a^2-x^2} \cdot dx = \frac{\pi\rho\, a\, V\, \Gamma_0}{2}$$

The velocity w at any point x is given by

$$w = \frac{\Gamma_0}{4\pi a} \int_{-a}^{+a} \frac{d}{dk} \cdot \sqrt{a^2-k^2} \cdot \frac{dk}{x-k}$$

$$= -\frac{\Gamma_0}{4\pi a} \cdot \int_{-a}^{+a} \frac{k}{\sqrt{a^2-k^2}} \cdot \frac{dk}{x-k} = \frac{\Gamma_0}{4\pi a} \int_{-a}^{+a} \frac{x-k-x}{\sqrt{a^2-k^2}} \frac{dk}{x-k}$$

$$= \frac{\Gamma_0}{4\pi a} \cdot \int_{-a}^{+a} \frac{dk}{\sqrt{a^2-k^2}} - \frac{x\,\Gamma_0}{4\pi a} \int_{-a}^{+a} \frac{dk}{\sqrt{a^2-k^2}} \cdot \frac{1}{x-k}$$

$$= \frac{\Gamma_0}{4a} \cdot -\frac{x\,\Gamma_0}{4\pi a} \cdot \left\{\frac{1}{\sqrt{a^2-x^2}} + \infty - \infty\right\}$$

The second term on the right is mathematically indeterminate, but physical considerations indicate that it must be zero, since otherwise the value of w would be different for $+x$ and $-x$.

Hence we write

$$w = \frac{\Gamma_0}{4a}$$

Taking this value for w we find that the induced drag w is given by

$$W = \rho\, w \int_{-a}^{+a} \Gamma\, dx = \frac{\pi\rho\,\Gamma_0^2}{8}$$

If we substitute in the expressions for A and w the total span b instead of the half span a we get

$$A = \frac{\pi}{4}\rho\, b\, V\, \Gamma_0;\ w = \frac{\Gamma_0}{2b}$$

The next question which arises is as to the form of the wing needed to secure the elliptical distribution of the circulation which has been shown to be that involving the least induced drag.

Now the lift A can be expressed also in terms of the "angle of attack," of the area of the plane, and of the square of the velocity of flight. Thus if t be the length of the wing chord the lift per centimetre of span is equal to $\rho\, V^2 t\,(c_1\, a^1 + c_2)$.

Here a^1 is the angle of attack and c_1 and c_2 coefficients. This angle of attack is defined as the angle which the chord to the wing makes with the line of flight.

But as shown in the first article the lift per unit of transverse length is also equal to $\rho\, V\, \Gamma$. Hence equating these two values we get

$$\rho\, V\, \Gamma = \rho\, V^2\, t\,(c_1\, a^1 + c_2)$$

Hence with a constant angle of attack t must vary in the same way as Γ and the best form of wing appears therefore in plan as a semi-ellipse or two semi-ellipses placed base to base as indicated in Fig. 23.

We are now in a position to estimate the effect of aspect ratio on the lift co-efficient of similar planes. The down draught w adds itself to the velocity of flight V so that the effective angle at which the air meets the plane is diminished by an amount equal to $\frac{w}{V}$.

Hence if a^1 be the angle of attack for an infinite aspect ratio the angle of attack for a real aeroplane will be $a^1 - \frac{w}{V}$.

Now it was shown above, that, for a wing elliptic in plan, $w = \frac{\Gamma_0}{2b}$ and that the total lift was $\frac{\pi}{4}\rho\, b\, V\, \Gamma_0 = A$.

Substituting for Γ_0 we get $w = \frac{2A}{\pi\rho\, V\, b^2}$ and $W = \frac{w}{V} \cdot A = \frac{2A^2}{\pi\rho\, V^2 b^2}$.

But the lift A can also be expressed in terms of the lift coefficient since we have

$$A = \rho\, V^2\,(c_1\, a^1 + c_2) \cdot F$$

where F denotes the area of the plane

Hence $\frac{w}{V} = \frac{c_a \cdot F}{\pi b^2}$ where c_a denotes the lift co-efficient, which for planes of the same profile in plan is independent of the dimensions. This lift coefficient is defined by the relation $c_a = \frac{2 \times \text{Total Lift}}{\rho\, V^2 \times \text{area of Wing}}$.

Hence if a^1 be the nominal angle of attack the real effective angle of attack for a wing of finite span will be

$$a = a^1 - \frac{c_a\, F}{\pi\, b^2}$$

Hence if in experiments with similar wing forms but different aspect ratios the nominal angles of attack are a^1_1 and a^1_2 respectively then the real angles of attack will be given by the relations

$$a_1 = a^1_1 - \frac{c^1_a \cdot F_1}{\pi\, b_1^2}.$$

$$a_2 = a^1_2 - \frac{c^1_a \cdot F_2}{\pi\, b_2^2}.$$

When the real angles of attack are the same $a_1 = a_2$ and $c_a' - c_a'' = c_a$ say. We then get the relation

$$a_1{}^1 - a_2{}^1 = \frac{c_a}{\pi} \cdot \left(\frac{F_1}{b_1^2} - \frac{F_2}{b_2^2}\right)$$

Every quantity in this expression is known from the data and observations, and consequently a comparison of this formula with test figures affords a drastic check on the validity of the theory. In a similar way it can be shown that at equal lift

coefficients, the drag coefficients c_{w_1} and c_{w_2} for similar wings are related by the expression

$$c_{w_1} - c_{w_2} = \frac{c_a^2}{\pi} \cdot \left(\frac{F_1}{b_1^2} - \frac{F_2}{b_2^2} \right)$$

In this way Metz and Mark deduced the lift curve and drag curves, for a plane with an aspect ratio of 5 to 1, from experiments on wings in which the aspect ratio ranged from unity up to 7 to 1. Their results are plotted in Figs. 24 and 25 from which it will be seen that the different observations yield remarkably concordant results. This is the more noteworthy since the wings experimented with were not similar in form.

The trailing vortex lines which on the foregoing theory extend behind a wing, make necessary a correction, if experiments in a wind tunnel are to be reduced to open air conditions. The reason for this will perhaps appear more clearly if we consider one

Fig. 24.

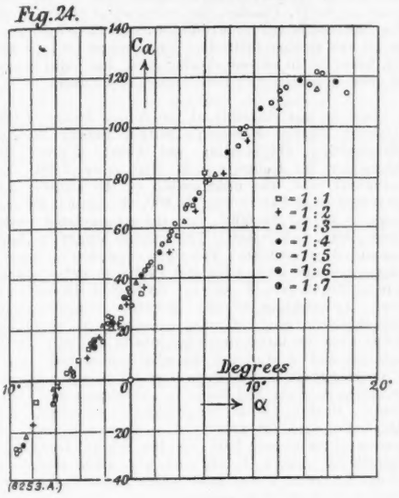


Fig. 25.

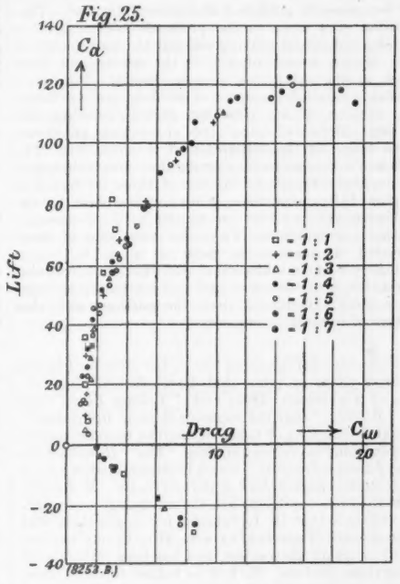
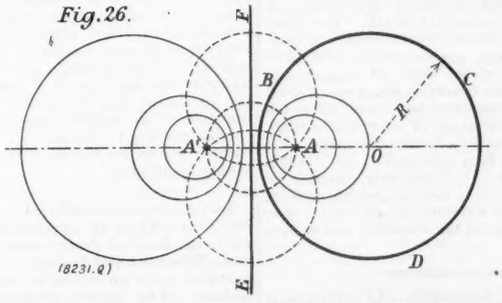


Fig. 26.



of these vortex lines only and replace it by a fine wire carrying a charge of $\frac{\Gamma}{4\pi}$ units of electricity per centimetre run. Here of course Γ denotes the circulation per centimetre run of the trailing vortex line which is replaced by this charged conductor. The equipotential lines round the wire will be exactly the same as the stream lines round the vortex line, and the velocity of flow at any point will be the same numerically as the force with which the charged wire would repel a unit charge situated at the point in question. The velocity, however, will not be in the direction of this force, but at right angles to the plane in which this force and the charged wire lie. This follows because, as shown on page 10 *ante*, if we differentiate the stream line function with respect to x we get the velocity of flow in the direction of y.

Suppose that parallel to our charged wire we have a conducting wall, connected to earth and thus at zero potential. What effect will this wall have on the distribution of potential round the charged wire? The answer is provided by Fig. 26 where the full line circles represent the equipotential lines round two oppositely charged wires at A^1 and A, and the dotted circles lines of force. From symmetry it is obvious that there is a line of zero potential at EF., midway between the two wires. Hence we can replace the wire at A by a conducting wall at EF connected to the earth and therefore at zero potential. The distribution of potential on the right hand side of this wall will therefore be the same as before the substitution. It follows conversely that the effect of placing a flat conducting wall parallel to a charged wire is the same as would be produced by placing an oppositely charged wire parallel to the original wire and twice as far from it as the wall is. Similarly when a vortex line approaches such a wall the actual flow of the fluid is the same as if the wall was replaced by a "mirror image" of the original vortex line.

The effect of a circular wind channel can similarly be obtained by considering the periphery of the channel as one of the equipotential circles shown in the figure, as for example the circle BCD. The position of the "image" A^1 is then found by making $OA^1 \cdot OA = R^2$ and the two points A^1 and A are known as inverse points.

Each line of the system of trailing vortices has, of course, its corresponding "image," and the wall constituting the boundary of the channel can be replaced by this imaginary sheet of trailing vortices constituted by the inverse points of each of the trailing vortex lines forming the real system.

As each line of the image is "oppositely charged" to the lines in the real system they reduce the potential due to these, and thus it follows that the induced downward velocity w is less in a wind channel than it is in free air. The amount of this reduction has been calculated in the way explained above. In the case of a wing having an elliptical distribution of the lift, the upward velocity due to the imaginary sheet of vortex lines is

$$w^1 = \frac{A}{4\pi R^2 \rho V} \left\{ 1 + \frac{3}{4} \left(\frac{2b}{D^2 x} \right)^2 + \frac{5}{8} \left(\frac{2bx}{D^2} \right)^4 + \&c. \right\}$$

where $D = 2R$ and R is the radius of the channel (see Fig. 26).

From this it follows that the reduction in the induced drag is

$$\frac{A^2}{4\pi R^2 \rho V^2} \left\{ 1 + \frac{3}{16} \cdot \left(\frac{b}{D} \right)^4 + \frac{5}{64} \cdot \left(\frac{b}{D} \right)^8 + \&c. \right\}$$

When the wing span b is equal to $\frac{R}{2}$ the induced resistance is about $12\frac{1}{2}$ per cent. less than in free air.

It may perhaps be added that the system of potential lines and stream lines shown in Fig. 26 is derived from the complex function

$$F(z) = i\phi + \psi = 2 \tan^{-1} \left(\frac{ix + y}{c} \right)$$

From which, on equating real and imaginary parts, we get

$$x^2 + y^2 - 2cx \coth \phi + c^2 = 0$$
$$\text{and} \quad x^2 + y^2 + 2cy \cot \psi - c^2 = 0$$

Here c denotes half the distance between A and A^1. Putting ϕ = a constant in the first of these gives one of the system of full line circles in Fig. 26 whilst if ψ be put equal to a constant we get one of the dotted circles shown.

(To be continued).

NOTES ON NEW BOOKS.

LAYMEN in this and in every country are under the impression that if a person knows a foreign language he is able readily to translate anything from that language into his own. The matter is not so simple, by far. A novel is never so well rendered as by a translator who is also an author. In order to render accurately a commercial specification it is necessary to know the market whence the specification emanates, or for which the material specified is required. Technical training is also a *sine qua non* for rendering accurately the description of any industrial plant. In the two latter instances, which are those which concern us most, a good technical dictionary is a great help, however capable a translator may be; it is to the translator what engineering textbooks and conversion tables are to the engineer. Such a dictionary is "*The Engineer's Pocket Technical Dictionary, French–English*," by Mr. Mark Lvoff. It gives in a small compass, as will soon be ascertained by daily use, a very large number of commercial and industrial terms, many of which are omitted from other similar works. The author has left out, and very rightly so, the obvious rendering of such words as *mathématique, électrique, technique*, &c., the place they would have occupied being taken by other terms useful to know. The book is one which can be recommended. It is published, at the price of 3*s.* 6*d.* net, by Messrs. E. and F. N. Spon, 57, Haymarket, S.W.1.

The German term "Unterbau," literally translated understructure, broadly corresponds to foundation work. The word forms the title of a volume on "*Unterbau*," by Professor W. Hoyer, of the Technical High School of Hanover. [Berlin: Julius Springer; price 1.95 dols.] To characterise the scope of the book we add that it belongs to the series of the *Handbibliothek für Bauingeniure*, edited by Professor R. Otzen, also of Hanover. The book before us forms the third volume of the second part of this collection, which describes the construction of railways and towns. The 187 pages of the book illustrated by 162 text figures, are well written, but do not enter much into detail, since they deal with earth and rock work, with railway embankments and cuttings, foundations and retaining walls, with crossings of railways and watercourses, and with tunnel construction. Literature references are given at the ends of the sections. More references would be desirable, particularly in the section on tunnels, which in its details is too much restricted to continental structures.

Those who have had an extended experience in teaching young students know how prone they are to fall into mistaken views. Many of them, for instance, must be warned against thinking that the length of the indicator diagram of a steam engine is altered when the distribution of steam is changed by such a process as linking-up. This being the case, it is much to be regretted that indicator diagrams are not always treated with care in reproduction in text-books. In a new book on "*Engineering Science*," which Mr. Arthur G. Robson has prepared for Messrs. Chapman and Hall, Limited, which is sold at 7*s.* 6*d.* net, this fault is seen. A series of seven diagrams are given to show how the steam distribution is changed to meet altered conditions of loading. In these there is a remarkable variation in the stroke, as shown by the length of the diagrams. Another matter that is striking in this book is the manner in which the deductions from experimental observations are treated. To those who appreciate that figures have a greater significance than as mere numbers, the deduction of a final result carried out to many places of decimals implies that the results are accurate to that degree. In this book there are examples where that condition does not

hold. To take a case, kinetic energy results are given to a ten-thousandth of a foot-pound, which are deduced from a flywheel of which the measurements are given, in inches and quarters, weights in exact numbers of pounds and time in exact numbers of seconds. Such matter is surely not calculated to inspire a student with an appreciation of the significance of the limits of accuracy in measurement. Another fault the author shows in this book is the manner in which he uses terms, of which the meaning is perfectly definite. An example will indicate best what is meant. An equation on page 186 shows that the author thinks that the dryness of steam may be considered as the ratio of the total steam less the *wet steam*, to the total steam. There is no doubt much that is good in the volume, but there are flaws that might have been avoided if the manuscript had been seen by some candid and critical reader.

Mr. J. Roussel's volume on "*Wireless for the Amateur*" is an authorised translation from the French, written by an amateur for amateurs. The author is secretary-general of the Société d'Etudes de Télégraphie et de Téléphonie sans Fil, a statement which will appeal to the general reader for whom the book is intended. It does not pretend to be a treatise on radiotelegraphy. Practically all the apparatus, the construction of which is described, was made by the author himself, and to assist the reader, the author gives, for instance, in the section on materials and tools, illustrations of the kind of pliers and files which he has found convenient to use. His short index, on the other hand, is poor. We find the term "kite aerial" three times in the index, while antenna, capacity, emitter, and filament are not mentioned. The author imagines the amateur to begin with a simple receiver and to work up to a complete receiving station. The preface is dated 1921; we do not expect any reference to dull emitters, therefore, and we have not found any. But the appendices are of more recent dates, and the unnamed translator has added a chapter on amplifiers suitable for the reception of any wave-lengths down to 150 metres, the original having dealt only with resistance-coupled high-frequency amplifiers; there are further welcome chapters on the transmission of both continuous waves and telephony on wave-lengths permitted to amateurs. The volume of 270 pages is published at a price of 14*s.*, by Messrs. Constable and Co., Limited.

The first edition of a useful work on iron metallurgy n three volumes, by the late Mr A. Ledebur, appeared in 1883. The first volume of the sixth, revised edition of this work, being the introduction to ironworks practice, "*Einführung in die Eisenhüttenkunde*," has recently been issued by Professor Hans Freiherr von Jüptner, Vienna. It contains articles dealing in a general way with the manufacture of iron, information covering combustion, fuels, data on furnace construction, slags, iron ore and its preparation, the book closing with particulars on the influence of various bodies, carbon, silicon, manganese, chromium, &c., on iron, diagrams and instructions being given of the combined systems. This first volume of the present edition contains over 550 pages, as against about 280 in the corresponding one published in 1883. Not having seen the later editions up to the fifth, we cannot say how far the present first volume of the sixth edition differs from the corresponding ones immediately preceding it, but we find many similar paragraphs and illustrations in both the first volume published forty years ago, and the latest one now under review. Nevertheless, this present volume I of the sixth edition is carefully got up, forms interesting reading and is a handy compendium on the first stages of iron manufacture. It contains, however, two statements which are quite out of place in a work on metallurgy, which will be resented—and quite rightly so—by a very large number of readers. The first is to the following effect: "The heavy competition of German commerce and industry was for England one of the principal reasons which led her to take part in the World War." This is so utterly preposterous that it is better left without comment. The other is a condemnation of our blockade of Germany during the war, there having been, according to the author, but not very clearly expressed by him, only two similar instances in olden times of such inhuman conduct, namely, attempts to ruin Egypt by diverting the flow of the Nile, which, fortunately for that country, did not succeed. The third attempt, made in the twentieth century, our blockade of Germany "does not speak favourably for the present state of Kultur of humanity." While he was on this topic the author might have brought in also the Blocus Continental decided upon in Berlin on November 21, 1806, by Napoleon I, directed against this country; it was intended to destroy our trade and marine, and brought us almost to ruin. The book is published by the Verlag Arthur Felix, Leipzig.

Few industries can show the extent and the variation of application of mechanism that is found in those in which vegetable fibres are converted into textiles. The processes are varied according to the type of raw material used and the quality and nature of the finished product, and the processes are so numerous that treatment within the confines of a single volume is only possible by the elimination of much of the detail. It is in consequence now becoming the practice to split up the treatment of the subject into separate sections. This is to be commended, as the textile industries have become so specialised that factories exist in which only some few of the stages in the operations are performed. Mr. Thomas Thornley, the head of the textile department of the Bolton Technical School, has shown his appreciation of the necessity for this division in "*The Middle Processes of Cotton Mills*," which Messrs. Scott, Greenwood and Son, recently published at a price of 15*s.* net. This provision of a work on the processes intermediate to spinning and actual weaving will suit the convenience of many readers whose interest in the earlier and later stages in the operations is only general. The work includes a detailed treatment of winding, reeling, bundling, warping, sizing, polishing, gassing, doubling and twisting. Details of many types of machines are shown in the course of the description of the processes. The work is a very satisfactory production, and although it was expressly written for the use of those interested in one part of the cotton trade, it has a wider sphere, for the machinery and processes are similar to those common in other textile trades. From the standpoint of those interested in mechanism there is much in cotton machinery to arrest attention, and this book contains in addition, a discussion of mill and machinery arrangements, powers required to drive the machines and other matters of interest to engineers.

Locomotive construction has so far advanced in the hundred years or more that have elapsed since the days of Trevethick (1803) and "Puffing Billy" and the "Rocket," that the engineer is more interested in critical discussions of types of engines than in general compendiums on railway engines. The "*Handbuch des Dampf-Lokomotivbaues*," which Professor Martin Igel, of the Technical High School of Berlin [Berlin: M. Krayn; price 15*s.*] has compiled, has the advantage over some of its rivals in that Dr. Igel started his compilation with the assistance of practical experts, after having lectured for 15 years on the subject, and has been unhampered by previous editions. He had no ballast to throw overboard; his historical introduction is very brief, and he comes quickly to constructive detail. Two hundred of the 600 pages of the volume, which is illustrated by 550 text figures, are devoted to brief illustrated descriptions of recent types of engines and tenders in which foreign countries are given a good deal more space than Germany, and there follow ten tables of the main dimensions of over 500 engines, accompanied in each case by a literature reference. A great deal of labour has been expended on these tables, and on the whole work. Unfortunately, there is no index, references are absent in the first general sections, and it is difficult to find a statement again which may have momentarily attracted the attention, and to hunt up the particulars.

Business Efficiency Exhibition.—An exhibition of office appliances organised by the Manufacturers' Trade Association in the Central Hall, Westminster, was opened on Wednesday last by Lord Kylsant, the President of the London Chamber of Commerce. Representative exhibits of the various articles designed to facilitate the conducting of business are to be seen everywhere, and their uses are demonstrated. The exhibition remains open until Saturday, February 16, and admission may be obtained by the presentation of business cards.

Auto-Train Collision at Palace Gates.—On November 22 last, a collision occurred between an auto-train consisting of an engine and two coaches, and engines in the loco coal yard at Palace Gates on the London and North Eastern Railway. The train was at the time running with the engine, bunker first, in the rear, and was under the control of the driver, with whom in the first compartment of the leading coach was the guard, the fireman being on the engine. The accident, according to Major G. L. Hall's report, appears to have been due to irregular action on the part of the fireman. The driver's control from the front coach is by pneumatic means, power control of the regulator being arranged by a simple mechanism when the driver is not on the footplate. When he is in the cab this is diconnected by pulling out a pin. It appears that the fireman at one stage pulled out this pin in order to expedite a movement by himself working the regulator, although it was not his duty to interfere in this way. The result was that on the driver again working his control a rod jammed the regulator handle in the open position and the fireman then found it impossible either to shut off steam or to stop the train with the brakes, or by reversing in time to avert the accident. The report concludes that the circumstances of the mishap are so unusual that there is little likelihood of a repetition of all the circumstances, but an alteration is suggested to the regulator control gear.

INDUSTRIAL NOTES.

A meeting of the committee of the National Wages Board was held last week at the Mining Association's Offices, Aldwych, when an important point in connection with the National Wages Agreement in the coal mining industry was raised by the Northumberland coalowners. They objected to a decision given by the Chairman of the Local Wages Board on what was contended to be a matter of principle. The miners' representatives had taken exception to certain expenditure, on what they considered to be development work, being charged to working costs; they considered that this expenditure should be charged to capital account. The matter was referred to the chairman of the District Board, who ruled that the expenditure should be charged to capital account. The coalowners while dissenting from the ruling, accepted the chairman's decision and placed the expenditure to capital account, but appealed to the National Board and to the general body of coalowners to support their contention. It was decided at the meeting to refer the point to Sir W. Plender, the independent chairman of the National Board for a ruling, which will be operative in all the mining districts. Since wages and profits are based on an income sharing basis, the point is one of great importance to both owners and miners.

Speaking last Saturday at the annual dinner of the Glasgow District Foremen's Mutual Benefit Society (Engineering, Shipbuilding, and Allied Trades), Sir Alexander M. Kennedy said that since 1899, the inaugural year, the membership of the society had increased from 345 to over 13,600, the annual income from 3,065*l.* to 200,000*l.*, and the accumulated funds from 2,400*l.* to 950,000*l.* The various benefits to date amounted to 340,000*l.* The sums expended on unemployment relief during the last twelve months showed a reduction of over 50 per cent. on that of the previous year. In addition to the monetary considerations opportunities were afforded members of acquiring information on latest developments in all branches of industry and of studying the most economical means of putting their knowledge into practice by lectures on technical subjects and visits to workshops and shipyards. Dealing with shipbuilding generally, Sir Alexander said all grades of management and all grades of workmen had, on the whole, faced the immediate position boldly and had made strenuous efforts to get to a cost basis which would enable new ships to be built at an economic price. In a large and complicated industry like shipbuilding such a task was not an easy one, particularly after the period of activity which war conditions had created. No one objected to high earnings, added Sir Alexander, but whatever the other merits of trade unionism, it could not be denied that its tendency was largely in the direction of an artificial standard of wages without specific relation to the volume of output. He also entered a plea for the more complete use of labour-saving appliances.

Besides the unions referred to in our last issue as being involved in the present dock difficulty, a new body, the National Amalgamated Stevedores, Lightermen, Watermen and Dockers' Union, set up last year following upon an unofficial dockers' strike, is also included. This union's claim is for an increase in wages of 2*s.* 6*d.* per day, with proportionate increase in piece-work rates. At the request of the Transport and General Workers' Union, the National Union of Railwaymen has decided to co-operate with the dockers' unions in the event of a strike, and all its members coming under the Shaw agreement will cease work simultaneously with the members of the Transport and General Workers' Union. A conference of employers' and dockers' representatives was held last Tuesday to discuss the situation, Mr. F. B. Allen, Chairman of the National Council of Port Labour Employers, presiding. The following statement was issued at the close:—"At the conference between the port employers and the Transport and General Workers' Union, Mr. Bevin stated the case of the union in support of the claim for a 2*s.* per day increase in wages and a guaranteed week. The port employers held a special meeting of their national council yesterday and will meet the representatives of the union at a further joint conference on Monday next, the 11th inst."

In the course of a note issued recently by Mr. Allen the statement is made that the port employers are in a large number of cases statutory bodies charged with the performance of certain duties, not with a view to profit earning, but so to manage that the dues and rates levied on ships and goods cover working costs and the maintenance of their systems. Mindful of Continental competition, they have no interest other than that of the community, namely, to keep charges to the shipowner, who is the customer of the port, at such a figure as will attract him there. Mr. Allen added that the majority of dock workers were receiving

a daily wage considerably in excess of the minimum. The shortening of the week to 44 hours had also increased the earning capacity of the workers, as thereby the period when overtime rates were payable was considerably accelerated. As much as 75 per cent. of the work at the Port of London was done on a piecework basis, and the earnings of pieceworkers were also considerably in excess of the 10*s.* per day minimum. Mr. Bevin had reminded the employers that they adopted the Shaw report as a whole; that was not denied, said Mr. Allen, but one of the conditions of the report was that the men should give a full day's work from 8 a.m. to 5 p.m. Lord Shaw put them upon their honour to give this, but experience showed that his expectations had not been wholly realised. The statements in the note in question have been controverted by Mr. Bevin and by Mr. Ben Tillett.

Mr. D. J. Owen, general manager of the Port of London Authority, states the following in a letter to the Press: "In view of the statements which have appeared as to the earnings of dock labourers, the Port of London Authority desire to make it known that the majority of the dock and warehouse labourers employed by them are permanent men, and that during the past three months 80 per cent. of those men earned an average of 90*s.* 6*d.* per week on piecework rates, while the balance on day work earned an average of 75*s.* 1d. per week. This compares with 36*s.* 6*d.* and 35*s.* 6*d.* respectively in the year 1914. It is, of course, fair to say that the earnings included a certain amount of overtime."

Pending negotiations on the question of wages paid to German seamen in British ports, the British trade unions have decided that German ships are not to be loaded, discharged or bunkered in British ports.

The Order of May 21, 1913, relating to the night employment of male young persons in factories where reverberatory or regenerative furnaces are used, is rescinded, and the special exception by which a male young person may be employed during the night in certain factories extends, so far as regards young persons of the age of 16 and upwards, to parts of factories in which these furnaces are used in connection with smelting of ores, metal rolling, forges, or manufacture of metal tubes and rods, and are kept in operation day and night to avoid waste of material and fuel; subject to conditions detailed in the new Order, No. 54, 1924 issued by the Home Office, Whitehall.

According to *The Iron Trade Review*, Cleveland, Ohio, San Francisco went through the entire year 1923 without a single strike of any consequence in the building trades. In fact, it may be said, without any strike at all, for the only ones which occurred were of a small number of union plasterers and pile drivers, the latter lasting less than two weeks. The union plasterers were working contentedly under the American plan until their international officers came and ordered them to strike on penalty of losing their charter. After a few weeks of idleness the men disregarded their international officers and returned to work. With these exceptions, the 20,000 union and non-union men in the building trades of San Francisco worked side by side every day throughout the year without trouble or controversy of any sort.

The long list of accidents (including many fatalities) which are reported year by year as being due to woodworking machinery, affords ample evidence of the need for special precautions and for a specially high standard of fencing in connection with these machines. Certain precautions have been made compulsory by the Woodworking Machinery Regulations, 1922, which came into force on January 1, 1923; and the Home Office have now prepared a pamphlet to assist occupiers of works in which such machinery is used by supplying information as to available guards and suggesting methods of working which will minimise the risk of accidents. The Home Office have also issued a revised edition of a pamphlet, originally issued in 1919, dealing with fencing and other safety precautions for transmission machinery in factories. Both pamphlets are illustrated with numerous plates and with illustrations of safety devices, &c., in the text.

The number of workpeople, other than seamen, reported as killed in the course of their employment in Great Britain and Northern Ireland during December last was 225, as compared with 209 in the previous month and with 208 a year ago. The distribution of these fatal accidents is as follows:—Railway service, 22; mines, underground, 93; mines, surface, 13; quarries, 8; factories, workshops, &c., 88; construction or repair of railways, 1.

The fact that the locomotive engineer is as long lived as the average American citizen in spite of his hazardous occupation, is shown by a "life table" recently prepared by the Metropolitan Life Insurance Company from figures compiled by the Locomotive Engineers Mutual Life and Accident Insurance Association. According to the table, the average engineer of 28 may count on living until he reaches the age of 69. Despite the hazards of the engineer's calling, insurance figures show a substantial decline in mortality amongst men in that occupation during the past ten years. Between the ages of 31 and 55 the progressive decline was 32 to 44 per cent. per annum. Above 55 years the figure varied, but this reflected the small number exposed to risk. A decline in the accident death rate from 318 per 100,000 in 1912, to 167 per 100,000 in 1922, shows how great has been the improvement in safety provisions for the operating personnel of American railways and accounts for a large part of the decrease in mortality at the age range of 31 to 55 years.

The present president of the Cleveland Institution of Engineers, Mr. H. B. Toy, in the course of his presidential address before that society, said it was deplorable to think that at the present moment, when the unemployed were counted by the million, coal, which cost only from 6*s.* to 10*s.* per ton a few years ago, was now sold at 30*s.* Hematite pig-iron was once sold in the Cleveland district at 2*l.* per ton and was now 5*l.* Steel plates 4*l.* 10*s.* per ton, now 10*l.* per ton. Nearly every other necessary commodity had proportionately increased. Mr. Toy could not recognise that any permanent good was likely to accrue from the numerous trade unions as at present constituted; although every individual should be quite at liberty to join any organisation which he considered likely to improve his social position, no coercion should be permitted which was likely to interfere with the freedom of others who did not wish to join any union. The restrictions at present in force relating to hours of work, overtime, amount of work a man may do, number of apprentices which may be employed, were surely wrong in principle, and until they were abolished he could see no prospect of competing with countries where such conditions did not apply. A man who by his own industry found employment for others was far more patriotic than those who, by virtue of their oratory, were poisoning the minds of workmen by alleging that they were entitled to live upon the energy and devotion of others who succeeded in life as the result of their industry. A man constantly posing as a friend of workmen was seldom, if ever, seen to use the least effort to find employment for them; his efforts were rather in the direction of causing dissension among those who were fully employed.

THE INSTITUTION OF ELECTRICAL ENGINEERS.—The Annual Dinner of the Institution of Electrical Engineers will be held at the Hotel Cecil, Strand, W.C. 2, on the 21st inst., when the President, Dr. Alexander Russell, will take the chair. The charge for tickets is 12*s.* 6*d.* each, and application should be made, before the 16th inst., to the Secretary, at the offices of the Institution, Victoria Embankment, W.C. 2.

BRITISH STANDARD MARKING FOR SWITCHBOARD BUS-BARS AND CONNECTIONS.—The British Engineering Standards Association has just issued Standards for the Marking of Switchboard Bus-Bars and Connections (No. 158, 1924). This publication contains rules for the colouring and marking of bus-bars and connections, the connection of generators to bus-bars, a description of the points of view of drawings and diagrams, with illustrations, arrangement of bus-bars and connections for three-phase systems, instructions regarding diagrams of switchboard connections. Copies of this publication may be obtained from the B.E.S.A. Publications Department, 28, Victoria-street, S.W.1, price 1*s.* 2*d.* post free.

STRESSES IN REINFORCED PIPES: ERRATA.—There were certain difficulties in deciphering some of the mathematical portions of the MS. of Professor von Sanden's letter on the above subject which appeared on page 87 of our issue of January 18 last. Owing to these a certain symbol was read as t where the author intended z. Thus in column 1, page 88, about one-third way down, for "t and $\frac{d^2 t}{dx^2} = 0$" read "z and $\frac{d^2 z}{dx^2} = 0$," and similarly three lines further down for "t and $\frac{d t}{dx} = 0$" read "z and $\frac{d z}{dx} = 0$." In the remainder of the article, wherever t occurs otherwise than as a denominator, it should be replaced by z. Thus a little above the middle of the second column on page 88, for "If $\frac{d t}{dx} = 0$ and $t = t_0$" read "If $\frac{d z}{dx} = 0$ and $z = z_0$," and similarly throughout. Also for t^2 in the formula given at mid-column, containing as a factor "$\frac{R^2 P}{E t} - t^2$" read "$\frac{R^2 P}{E t} - z_2$." There is another error in the formula for K_2 near the bottom of the second column, which should read $K_2 = (\cosh n l + \sin n l)/N$.

DETERMINATION OF SILICON IN IRON-SILICON ALLOYS BY THEIR PHYSICAL PROPERTIES.*

By T. D. YENSEN, Research Department, Westinghouse Electric and Manufacturing Company.

WHILE the determination of silicon in iron and steel by ordinary chemical analysis is a comparatively simple matter, its determination in low carbon alloys by certain physical tests is sometimes sufficiently accurate and is simpler and much less expensive than the chemical analysis.

In the course of our investigation of the magnetic properties of Fe-Si alloys, we have found two physical characteristics of these alloys that are readily determined, and are simple functions of the silicon content, and at the same time are not sensitive to variations in the heat-treatment. These characteristics are: (1) the electrical resistance and (2) the hardness. Sometimes one of these

Fig. 1. ELECTRICAL RESISTANCE OF IRON-SILICON ALLOYS.

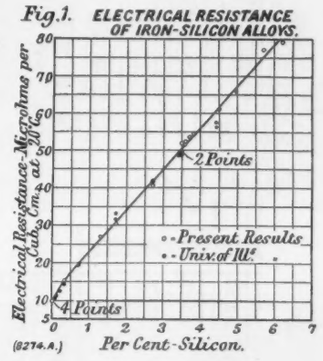
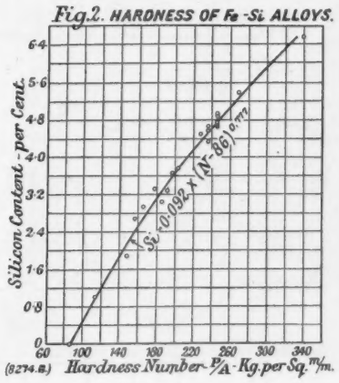


Fig. 2. HARDNESS OF Fe-Si ALLOYS.



can be used to advantage and sometimes the other.

The relationship between Si and electrical resistance is shown in Fig. 1. This curve is composed of two straight lines with a bend at Si = 0·35 per cent.

In the same way the relationship between Si and hardness is shown in Fig. 2 and can be expressed by the equation:

$$Si = 0{\cdot}092 \times (N - 86)^{0{\cdot}777}$$

where:

N = the Brinell hardness number = $\frac{P}{A}$

where:

P = load in kg. on a 10-mm. diameter steel ball

and

A = the area in sq. mm. of the impression made by the 10-mm. ball on the sample.

From the above equations it will be seen that the electrical resistance of pure iron (Fe) is 9·6 microhms, and its hardness number is 86.

Of the two methods of analysis the electrical resistance probably is the more accurate, although either one should give the silicon content within 0·1 per cent. If samples are available in the form of rods of uniform cross-section, electrical resistance determinations can be made at the rate of one or two per minute, each determination giving the average resistance for the rod. Methods have also been developed for determining the resistance of ring test-pieces. The hardness method has the advantage that any form of sample can be used provided it has sufficient body. (It should be at least ½ in. thick, and ½ in. wide with a flat, smooth surface where the impressions are to be made). Impressions, at the rate of one per minute, can be made on different portions of the sample, thus giving information both as to the average composition and to the homogeneity of the sample.

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* Paper read before the American Institute of Electrical Engineers in January, 1924.

THE SETTLEMENT AND RIGHTING OF A FACTORY BUILDING IN HOLLAND.

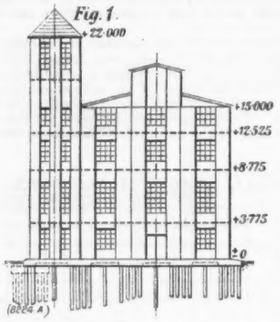
The character of the Dutch fenlands renders necessary heavy expenditure on dykes and other engineering works. Buildings and other structures have, as a rule, to be carried on piles driven down to solid strata, in spite of which precaution, however, it often happens that settlement or horizontal movement occurs without its cause being exactly understood. An interesting example of this is the case of the factory buildings of the Jurgens Oil Mill Works at Zwyndrecht, Holland. The building affected is situated alongside the River Maas, between the river bank and a dyke. The site was reclaimed by sand filling, deposited hydraulically, to a depth of 4½ metres.

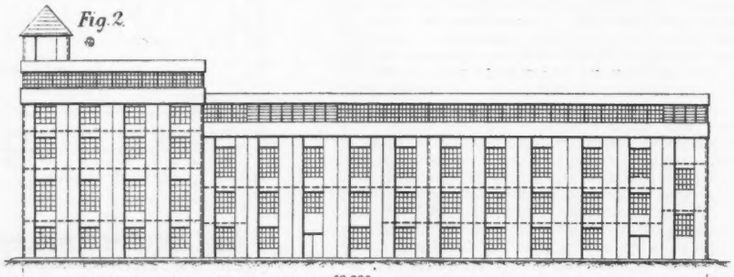
In 1915, when it became necessary for Holland to produce as much as possible of her own foodstuffs, the Jurgens Margarine Works Company decided to erect on the site in question an oil mill and refinery, with oil hardening plant for the manufacture of margarine. The building was therefore required to carry heavy machinery, tanks and other apparatus, and the arrangement involved a height of 20 metres.

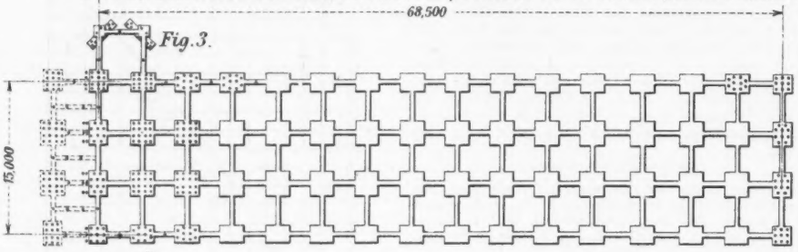
In order to erect it cheaply and quickly it was decided, contrary to the usual practice on such ground, not to excavate the sand fill, but to place the foundations on piles driven through this stratum. The top of the piles stood above normal water level and they were therefore creosoted, the driving and creosoting plant limiting the length to about 20 m., which, as it happened, was the greatest length procurable at the time. Test piles showed for the last 30 blows a movement of 30 centimetres, which, it was calculated, should serve for a static load of 50 tons per pile. The load proposed was only 5 tons per pile, giving a factor of safety of 10, which was considered ample. It was thought that sufficient resistance would be obtained with the 20 metre piles extending into a bed of fine sand 17 metres below ground level, and that it was unnecessary to carry them deeper into a layer of coarse sand and gravel 5 metres below. It would, in fact, have been scarcely possible to drive longer piles successfully, for the resistance proved to be so great that even the 20 metre lengths began to fail by crushing under the tup.

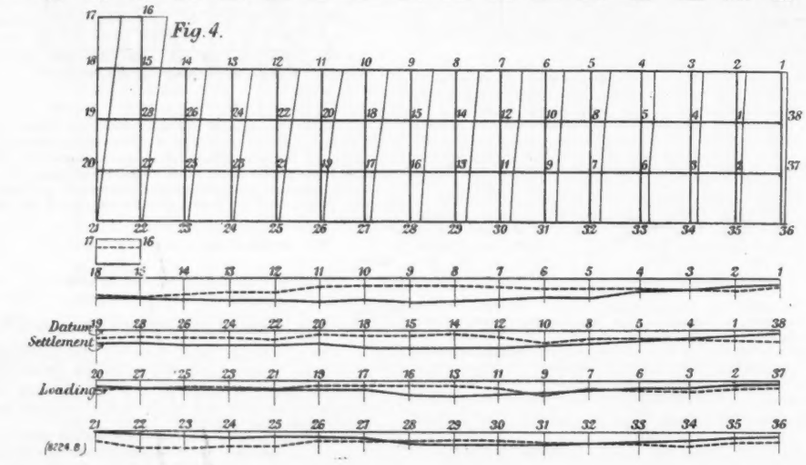
At the end of a year of strenuous work the factory was completed and in operation. Four years later the engineers had to face the fact that the oil-hardening building had settled to a serious extent. This building is illustrated in Figs. 1 to 3, above, while Fig. 8, on the opposite page, shows the extent to which the walls were out of plumb; the three drawings give respectively elevations and foundation plan of the structure. It was of steel frame work with brick wall filling. Borings revealed the following facts: the uppermost stratum consisted of the 4½ m. of reclamation sand filling. Below this was a thickness of 13 m. of peat mixed with some clay; under this were 5 m. of fine sand, and below this again solid ground of coarse sand and gravel. As already stated the piles penetrated into the bed of fine sand, being driven to refusal. The sand filling produced a load of about 8 tons per square metre on the layer of peat below tending to compress it. The resistance of the piles was made up of (1) the resistance in the layer of sand filling; (2) that offered in the peat; and (3) the resistance of the bed of fine sand beneath. Compression of the peat reduced the resistance offered in that layer of material, and that offered by the sand filling would of course, completely disappear if the piles sank as fast as the peat settled. Thus the resistance taken at first as 20 tons for the upper sand and 30 tons for the peat and lower sand, would in such circumstances be reduced to about 15 tons only in the lower sand. As a matter of fact, the upper beds, in sinking, tended to pull the piles down, the force exerted being estimated as high as 15 tons, and under these conditions the total downward force was greater than the resistance, and the piles actually tended to drop away without external loading. This actually happened with isolated piles. For grouped piles the conditions were different.

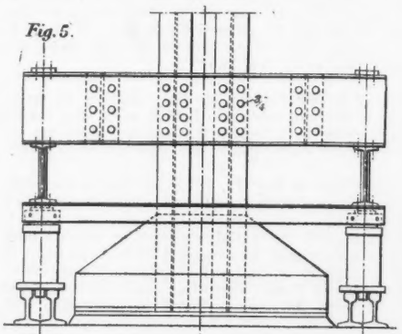
For most of the building the load was not more than 3 tons per pile, except under the tower in which there was a water tank. For this part the load worked out at 18 tons for each of six piles; this was certainly excessive. As settlement continued and the tilting of the building subjected the steel frame work to strains which threatened to cause its collapse, it became imperative to deal with the

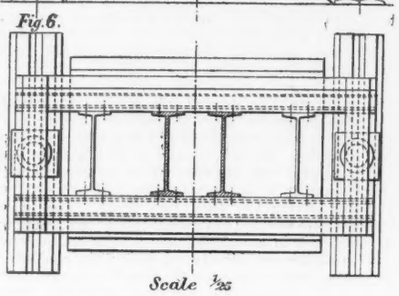


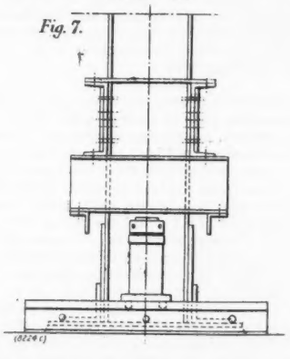












situation. As the best way of doing this it was decided to right the building, lifting the whole in such a manner as not to interfere with the continuous operation, day and night, of the oil-hardening plant. The work of raising this building of two and three stories, measuring 68·5 m. by 15 m. (225 ft. by 50 ft.) and with a tower 25 m. (82 ft.) high, full of plant, machinery, tanks and piping, through a distance of 70 cm. (2 ft. 1¾ in.) was no ordinary task, as may be imagined, and naturally required careful planning and the exercise of great care in execution.

Fig. 3 shows the grouping of the piles. The pile heads in each group were covered by concrete block cappings 2 ft. thick; on these stand the main steel columns of the structure. In the upper lay-out, Fig. 4, are set out horizontally from each column centre the amount of the settlement at that point. In the lower diagram the amounts are set off vertically and the continuous lines show the settlements measured down the line of columns. The dotted lines in this diagram indicate the loads on the columns. The greatest settlement was measured at columns 16 and 17, and amounted to 70 cm. (2 ft. 1¾ in.) as already stated. This is explained by the isolated position and the heavier loading on the piles at this point. At column 21 the settlement was practically nil. It may here be mentioned that piles driven subsequent to the construction of the building and supporting only an extension of the concrete floor (shown dotted to the left of Fig. 3) sank in the same way as those under the building. This appeared to confirm the theory that it was possible for the piles to sink, due to the settlement of the sand filling and the nature of the ground below.

The building was constructed of columns with heavy steel floor beams and concrete floors; steel diagonals were arranged in the walls. The structure proved to be sufficiently strong to stand considerable local bending, as, for instance, at columns 5, 16, 28, &c., as shown in the lower diagram of Fig. 4. This was taken as proof of the feasibility of righting it again. It was decided to make a start at the tower, and for this purpose all columns of the three left-hand rows in Fig. 3, except 21, 22 and 23, were fitted with short lengths of heavy steel channel arranged as in Figs. 5, 6 and 7. These were riveted to the columns, braced with stiffeners and fitted underneath with short lengths of steel joists, tied together by angles.

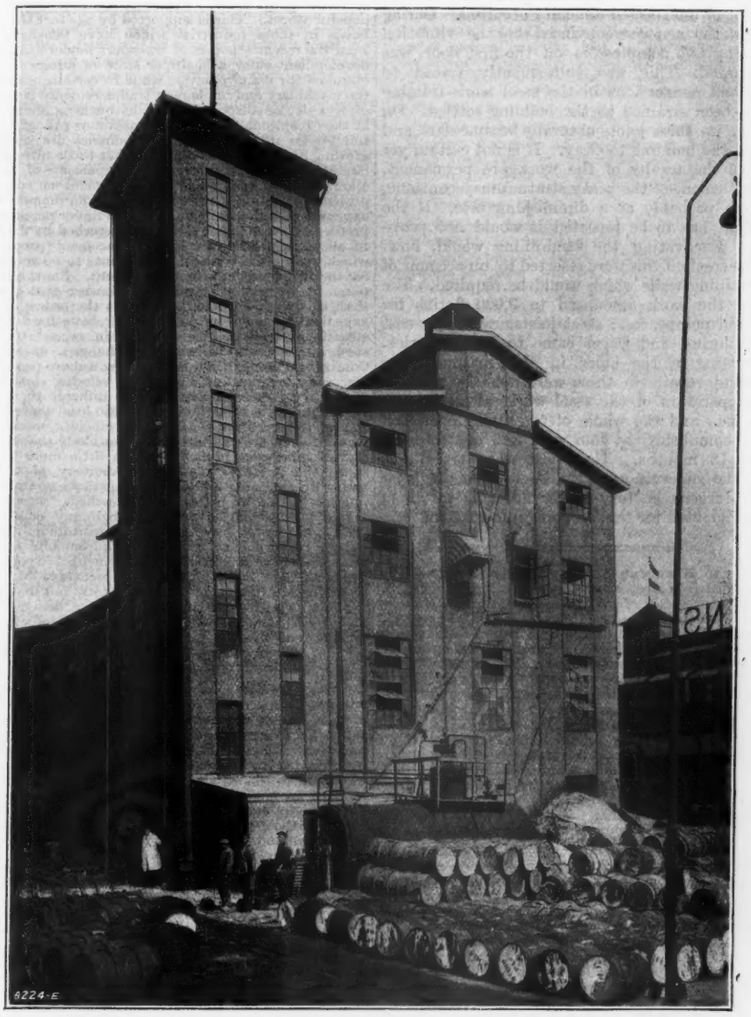


FIG. 8.

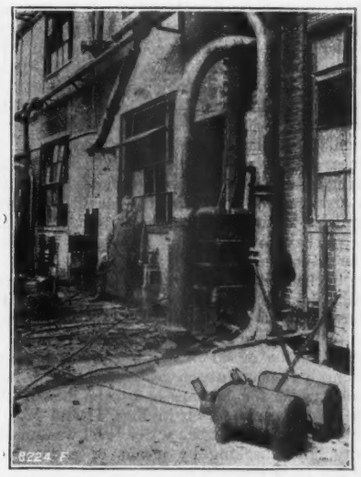


FIG. 11.

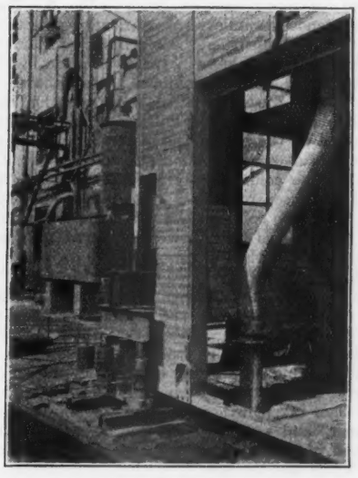


FIG. 12.

Fig. 9.

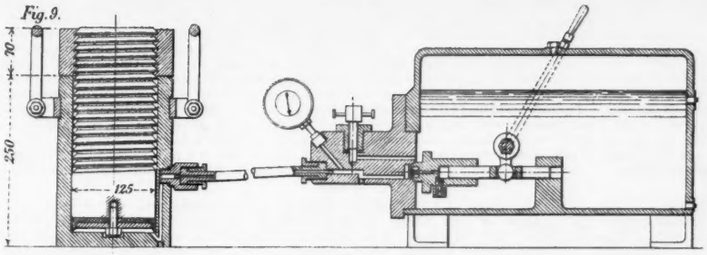
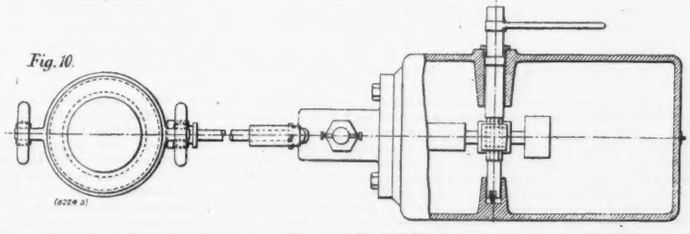


Fig. 10.



Outside the column footings were laid lengths of rails, and on these were placed hydraulic jacks with the object of exerting an upward pressure on the joists. The jacks used are shown in detail in Figs. 9 and 10. The pump was fitted with a gauge, and the ram was screwed and fitted with a large nut, which could be run down quickly on to the shoulder of the cylinder as soon as the ram lifted. The pitch of this thread was 4 to the inch. It was found necessary to raise the pressure to about twice the calculated load on a column, due to the fact that these were not lifted all together, but in succession, with the result that on account of the stiffness of the walls, part of the load on neighbouring columns was carried by those being lifted. The arrangement of the jacks under the columns is well shown in Figs. 11 and 12, in which also some of the pumps are to be seen.

The actual rise was gauged by a water level. To assist in checking, a white vertical mark was painted on each column. The lower end of this was at a uniform distance from the base, on all columns. The upper end was at the height to which the lower end had to be raised in the process of levelling. The length was thus in each case equal to the distance through which the columns had to be raised. The white marks can be seen in Figs. 11 and 12. On trial it was found that the water level was unsatisfactory, and checking by means of a surveyor's level had to be resorted to.

Before lifting operations were commenced, twelve additional piles were driven near columns 16 and 17, the heads being connected in groups of six by reinforced concrete beams, as shown in Fig. 3. These were intended to relieve the overloaded piles under the tower, should there be a tendency for further settlement to develop. A trial was made in September, 1921, on the columns named above. It soon became apparent that the worst point had been chosen on account of the stiffness of the end wall. The load on the beams was more than double the normal load on the columns, to effect a lift. As soon as the column footings and the foundation blocks were separated half-an-inch it was observed that while the columns had risen, the foundations had sunk. This trial, however, proved the feasibility of the method proposed.

The winter of 1921–22 was occupied in fixing the cross-channels to the remaining columns, cutting out the concrete under the columns and making everything ready for lifting the whole in 1922. In this operation the work was undertaken in sections. One third of the building was raised one quarter of the required amount; the middle third was then taken in hand and treated in a similar manner, and subsequently the last third. The process was repeated, working with 48 jacks, until the whole was levelled.

After some preliminary experience the jacks were fully extended before re-setting, and 2 in. bar iron, stacked crosswise, was used for packing under the column footings. The columns were lowered on to this and new concrete was then laid round and under the columns. These concrete bases were made large enough to carry the rails on which the jacks were placed. The utmost care was necessary in the work, which was completed during the summer of 1922. After every ¼ in. lift all pipes, electrical leads, apparatus and machinery had to be inspected for leaks and any necessary repairs effected. Driving belts had to be lengthened or shortened. The plant on the ground floor required the most attention, as this remained stationery, while the building was lifted. The pipes, including an 8 in. water main and a 6 in. gas pipe had to be lengthened at each stage. In the 8 in. water main a 5 m. length of flexible metallic pipe was inserted; this may be seen in Fig. 12. For the gas supply a water-sealed pipe permitting 1 m. of movement was employed.

In the centre of the building on a single concrete raft there were ten oil-hardening boilers of 7 m. (23 ft.) height, connected together by numerous pipes for gas, water, steam and oil. As it was impossible to alter these constantly without interrupting operations, the whole plant was suspended from the floor above. The factory was in continuous operation throughout, necessitating constant attention to the plant, while the work could, of course, only be carried on in very small stages. The pipes conveyed water, steam, gas, water-gas, hydrogen under 110 lb. per sq. in. pressure, sulphuric acid and other substances, and any failure would have been liable to cause a serious accident.

The success of the preparative work and care taken throughout is evidenced by the fact that no accident or unexpected difficulty occurred. During the work the men were convinced that the vibration caused by two compressors on the first floor, was accentuated. This was subsequently traced to joints and connections in the steel work framing having been strained as the building settled. On levelling up, these joints naturally became slack and allowed the building to sway. It is not certain yet whether the results of the work are permanent. The settlement of the peaty stratum may continue, although probably at a diminishing rate. If the operation has to be repeated it would not prove costly. Excavating the sand-filling would, however, be costly if this were resorted to, on account of the retaining walls which would be required. The cost of the work amounted to 9,000 florins for jacks and pumps, &c.; steel joists, rails, &c., cost 10,000 florins, and wages came to 13,000 florins. The cutting of the holes in the masonry and floors and repairs to these were done by masons. The preparation of the steel work, alterations to pipes, &c., and the whole of the lifting operation were accomplished by four men and one foreman in the 18 months. The work was carried out under the supervision of Mr. C. A. Salm, engineer of the Jurgens Factory at Zwyndrecht, to whom we are indebted for the foregoing information.

Improved Bessemer Converters and Linings.—We read in *The Iron Age*, New York, that Mr. Richard S. McCaffrey, professor of mining and metallurgy, University of Wisconsin, Madison, received on January 11, notice that letters patent have been issued to him on a new process for "bessemerizing" iron. Application for the patent was made about two years ago. Mr. McCaffrey states that the patent is for improved converters and linings for converters in the production of Bessemer steel. There are certain furnaces treating a pig iron high in chromium and using a converter lining of siliceous material with the result that the lining lasts only for 60 to 70 blows. The patent is for a chromite lining, a material which should have a life of from 800 to 1,000 blows. With this chromite lining, he adds, it is possible to eliminate phosphorus from the steel and make a higher quality product than is possible with the use of a siliceous lining and chrome bearing pig iron.

Embrittlement of Boiler Steel.—According to *The Iron Age*, New York, the American Bureau of Standards has made a microscopic examination of a boiler plate which had developed cracks in service. Such steel is generally referred to as caustic embrittled steel. It has generally been assumed that embrittlement occurs as a result of the absorption of nascent hydrogen, which has its origin in the interaction of iron and caustic alkali. The alkali results from the hydrolysis of certain additions made to the feed water, and this alkali concentrates in crevices around the rivets and similar places. Cracks appear in the plate only as a result of a combination of two conditions, stress in the metal and chemical attack by the alkali. The examinations made confirm those of other investigators in showing that caustic embrittlement in an intercrystalline phenomenon, that is, the cracks have an intercrystalline course and are not diverted by inclusions or other visible impurity within the steel. They also confirm the assumption usually made that the production of hydrogen is accompanied by oxidation of the iron. In the specimens all the marks were found to be filled completely with oxide of iron, even to the innermost ends of the finest microscopic cracks, where the chance of oxidation from without would be entirely negligible.

The Panama Canal.—Five hundred and-six commercial vessels made the transit of the Canal in December, 1923. This exceeded the previous high record (July, 1923, with 474 ships) by 32 vessels, over one a day. The average per day in December was 16·32. Tolls to the amount of 2,335,729·81 dols. were paid on the 506 commercial transits and 61·50 dols. on 16 launches, making a total tolls collection for the month of 2,335,791·31 dols., exceeding that of any previous month since the opening of the Canal. July, 1923, is the nearest with a total collection on all traffic of 2,124,849·27 dols. The average daily collection of tolls for the month on all traffic was 75,348·11 dols., and on commercial traffic only was 75,346·12 dols. These are the highest averages for any month since the Canal has been in operation. Traffic through the Panama Canal in the calendar year ending December 31, 1923, exceeded that in any previous year. The number of commercial vessels making the transit during the year was 5,037. Their aggregate net tonnage, Panama Canal measurement, was 24,737,437 tons. They carried 25,160,545 tons of cargo, and paid 22,966,838·18 dols. in tolls. As compared with the year 1922, the traffic in 1923 increased as follows: number of ships, 68·07 per cent.; Panama Canal net tonnage, 90·38 per cent.; tons of cargo, 83·51; tolls collected, 82·65 per cent.

NOTES FROM SOUTH YORKSHIRE.

Sheffield, Wednesday.

Iron and Steel.—Now that the market appears to have recovered somewhat from the scare created by the advent of a Labour Government and from the worst effects of the railway strike, conditions are assuming a more hopeful aspect. This is supported by the fact that order books in those industries which have benefited most from the recent schemes of transport modernisation and development show a healthier state of affairs than has obtained for many months, while in certain branches of the machinery and implement trades evidence is reported of a welcome disposition to do business more freely at the exceptionally attractive rates now ruling. Potential buyers in this and other countries are showing a growing appreciation of the fact that those rates are not likely to be repeated when the expansion of business allows a more reasonable apportionment of costs. At present, quotations represent rock-bottom manufacturing expenses with the addition of only a minor percentage of profit. The armament section is perturbed by the threat to abandon the light cruiser replacement programme, which, before the political change, was to be accelerated for the further relief of unemployment. Steps are being taken by associated employers to ensure that not only shall this work be placed, but that the orders shall be expedited as much as possible to relieve hard-hit constructional trades. The position in regard to heavy steel manufacture is largely unchanged, except that Continental competition is becoming a more pronounced feature. Belgium and France are offering considerable tonnages at reduced rates. It is difficult to trace to what extent this material is going into local consumption, though judging from the fact that official quotations for local supplies are unaltered, it seems likely that Sheffield and district users prefer to pay a little more for steel of reliable quality, the regular delivery of which is assured. Hematite and pig-iron constitute an unchanged market so far as prices are concerned. Supplies are ample for immediate needs, though any considerable growth in forward buying would necessitate an increased output at furnaces. Supplies to automobile engineers are a feature of engineering requirements. Special steel products show but a slow rate of recovery, largely due to adverse tariffs in overseas markets, but hand tools for mining and quarrying are in rising demand, while engineering masters are renewing works stocks. The trough rent dispute in the table and butcher blade section of the cutlery industry is having an adverse effect on stainless steel consumption.

South Yorkshire Coal Trade.—Both on manufacturing and domestic account current output fails to satisfy the demand, owing to the accumulation of orders resulting from the dislocation of the railway strike. Collieries are doing their utmost to reduce these as quickly as possible, but meanwhile prices remain firm at recently-advanced rates, with a further addition of 1*s.* per ton in the case of Yorkshire hards. Merchants report difficulty in securing sufficient housecoal to meet the needs of their customers. Cobbles and nuts are going steadily inland. Lancashire is taking a fair supply of slacks. All classes of coke are steady at unchanged rates. Quotations: Best handpicked branch, 35*s.* to 36*s.*; Barnsley best Silkstone, 30*s.* 6*d.* to 32*s.*; Derbyshire best brights, 30*s.* to 32*s.*; Derbyshire best house coal, 26*s.* to 27*s.*; Derbyshire best large nuts, 24*s.* 6*d.* to 25*s.* 6*d.*; Derbyshire best small nuts, 18*s.* to 20*s.* 6*d.*; Yorkshire hards, 25*s.* to 27*s.*; Derbyshire hards, 24*s.* to 25*s.*; rough slacks, 12*s.* 6*d.* to 13*s.* 6*d.*; nutty slacks, 10*s.* to 12*s.*; smalls, 7*s.* to 9*s.*

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

Middlesbrough, Wednesday.

The Cleveland Iron Trade.—Business in Cleveland pig-iron is on an extremely limited scale. Prices are down a little, but are still much too high to tempt customers to operate to any extent. Continental competition in the home markets is somewhat less keen than it has been, but foreign iron can still be bought on comparatively very low terms. Recent purchases of Continental pig-iron for consumption in this district are understood to have been on quite a considerable scale. No. 1 Cleveland is 100*s.*; No. 3 g.m.b., 98*s.*; No. 4 foundry, 96*s.*; and No. 4 forge, 95*s.*, all f.o.t. makers' works, and f.o.b. Tees.

Hematite.—A weakness in the East Coast hematite branch hardly amounts to actual fall in prices. Makers are fairly well off for work, but experience difficulty in securing orders to follow on contracts approaching completion. Nos. 1, 2 and 3 are 102*s.*; and No. 1 is 103*s.*, but possibly these figures could be shaded.

Foreign Ore.—There is little or nothing doing in foreign ore. Quotations were nominally upheld on the basis of 24*s.* for best rubio.

Shipments of Iron and Steel.—January shipments of iron and steel from the Tees—including 5,329 tons of pig-iron loaded at Skinningrove—total 95,799 tons, of which 41,270 tons were pig-iron, 4,790 tons manufactured iron, and 49,739 tons steel. Of the 35,941 tons of pig-iron sent from the Tees 27,110 tons went abroad, and 8,831 tons went coastwise; of the manufactured iron shipped, 4,076 tons went abroad, and 714 tons went coastwise; and of the steel cleared, 41,024 tons went abroad, and 8,715 tons went coastwise. Italy, with 7,465 tons, was the largest importer of pig-iron: Wales received 6,275 tons; Belgium, 4,929 tons; America, 3,430 tons; Denmark, 3,050 tons; Scotland, 1,980 tons; Germany, 1,853 tons; and Danzic, 1,315 tons. Natal, 1,900 tons, was the principal customer for manufactured iron. India was again the heaviest purchaser of steel,

receiving 15,286 tons. Other chief importers were: Japan, 5,241 tons; Cape of Good Hope, 4,406 tons; Egypt, 2,358 tons; and Norway, the Straits Settlements, New South Wales, and Queensland, each over 1,000 tons.

Blastfurnace Coke.—Durham blastfurnace coke shows downward movement. Good medium qualities are now round about 35*s.* 6*d.* delivered to local users.

Manufactured Iron and Steel.—Finished iron and steel manufacturers have a good deal of work on hand, but their producing capacity is now enormous. Large orders are speedily executed, and there is keen competition for contracts in the market. Common iron bars are 12*l.*; iron rivets, 14*l.*; packing (parallel), 9*l.*; packing (tapered), 12*l.*; steel billets (soft), 9*l.*; steel billets (medium), 10*l.*; steel billets (hard), 10*l.* 5*s.*; steel boiler plates, 13*l.* 10*s.*; steel ship, bridge, and tank plates, 10*l.* 5*s.*; steel angles and joists, 10*l.*; heavy steel rails, 9*l.*; fish plates, 13*l.*; black sheets, 13*l.* 5*s.*; and galvanised corrugated sheets, 18*l.* 10*s.* to 18*l.* 15*s.*

Imports of Iron and Steel.—Returns issued this week by the Tees Conservancy Commission give the imports of iron and steel to the Tees from Holland, Belgium, France, Norway, Sweden, Germany, and coastwise for the months of November, December and January, together with the statistics for the corresponding months a year ago, and for the same pre-war months of 1913–14. Imports of pig-iron for the past three months are given at 1,691 tons, against 2,015 tons a year ago, and 50 tons in the pre-war period. Arrivals of crude sheets, bars, billets, blooms, and slabs for the months just ended amounted to 11,750 tons, against 19,763 tons a year ago, and 11,200 tons in the pre-war period; and unloadings of plates, bars, angles, rails, sheets, and joists for the past three months reached 3,147 tons, against 3,312 tons a year ago, and 5,869 tons in the pre-war period.

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Scottish Steel Trade.—There has not been much change in the Scottish steel trade position over the week, but there is, if anything, a little more doing. Since the close of the railway strike, material has been moving a little more freely, and with the shipbuilding industry gradually getting better, a healthier tone is anticipated before long. Quite a fair tonnage is now on order, but the output of most works is so large that a decided buying movement will be necessary before they can hope to be in full swing. Inquiries are rather better, and although buyers realise that present prices are quite favourable, there are two things keeping back dealings—cheap Continental prices which may ultimately force down home quotations; and the generally unsettled state of foreign markets. Local sellers are offering very keen quotations for export orders in the hope of regaining lost ground. In the black-sheet trade a fair amount of activity still rules and the output is very satisfactory. The following are the current prices:—Boiler plates, 13*l.* 10*s.* per ton; ship plates, 10*l.* 5*s.* per ton; sections, 10*l.* per ton; and sheets, 12*l.* 10*s.* per ton, all delivered Glasgow stations.

Malleable-Iron Trade.—Employment in the West of Scotland malleable-iron trade is still only moderate, and producers cannot see very far ahead. Orders on hand are quickly run off, and fresh business is not very heavy. For re-rolled steel the demand has fallen away to some extent. The price of "Crown" bars keeps steady at 12*l.* 10*s.* per ton, delivered Glasgow stations.

Scottish Pig-Iron Shipments.—The shipments of Scottish pig-iron from Glasgow Harbour for the week ending last Saturday, February 2, amounted to 1,077 tons. Of that total, 1,017 tons went foreign and 60 tons coastwise. For the corresponding week of last year the figures were 1,937 tons to overseas markets, and 147 tons coastwise, making a total shipment of 2,084 tons.

Pig-Iron Trade Wages Reduced.—The following intimation has been made to Messrs. James C. Bishop and Owen Coyle, joint secretaries of the Board of Conciliation for the Regulation of the Wages in the Pig-Iron Trade of Scotland, by Messrs. Kerr, MacLeod & Macfarlan, C.A., Glasgow:—"In terms of the remit, we have examined the employers' books for October, November, and December, 1923, and certify that the average net selling price brought out is 4*l.* 19*s.* 5*d.*" This means that there will be a reduction in the wages of the workmen of 6 per cent. on basis rates.

Scottish Shipbuilding.—Conditions at the shipyards throughout the country are slowly but surely getting better, and quite a satisfactory tone now prevails. Workers are gradually being absorbed, and if new contracts continue to come along with any regularity, and labour troubles are avoided, we can look forward to a much improved output for the present year. For the month of January, there was the very good return of nine vessels of 36,917 tons from the Clyde yards, which was well over the average January output, and was the third or fourth largest total for that month. On the Forth there was launched a vessel of 2,773 tons, and also the vessel of 2,400 tons launched on January 6. These make a total Scottish output for January of 11 vessels of 42,090 tons. New contracts have been rather more numerous of late, and some owners are of opinion that delay in placing their orders, where these are actually required, may be a costly matter. It is known what charges are to-day, and many are of the belief that lower costs will not prevail yet awhile, and that the tendency is indeed in the other direction. During the past month, over a dozen new vessels were placed on the Clyde alone, and when those fixed up since the boiler makers' strike ended are added it cannot be gainsaid but that the shipbuilding industry is improving.

NOTICES OF MEETINGS.

THE INSTITUTION OF MECHANICAL ENGINEERS.—Friday, February 8, at 6 p.m., at Storey's-gate, S.W.1. Extrageneral meeting: "Repair and Upkeep of Pneumatic Tools," by R. W. Wilson.

THE INSTITUTION OF HEATING AND VENTILATING ENGINEERS.—Monday, February 11, at 2.30 p.m., the annual general meeting will be held at the Holborn Restaurant (Kingsway Salon), High-holborn, W.C.2. After the general business an address on "Industry and Invention" will be delivered by Sir George Croydon Marks, and discussed.

THE INSTITUTE OF METALS. SCOTTISH LOCAL SECTION.—Monday, February 11, at 7.30 p.m., in the rooms of the Institution of Engineers and Shipbuilders in Scotland, 39, Elmbank-crescent, Glasgow. Paper on "The Properties of Some Non-Ferrous Alloys," by Mr. Robert Hay, B.Sc.

CLEVELAND INSTITUTION OF ENGINEERS.—Monday, February 11, in the Hall of the Cleveland Technical Institute, Corporation Road, Middlesbrough, at 6·30 p.m. precisely, a paper will be read on "Iron Portland Cement," by Mr. Edwin H. Lewis.

THE INSTITUTION OF ELECTRICAL ENGINEERS. SCOTTISH CENTRE.—Tuesday, February 12, at 7.30 p.m., at the Rooms, 207, Bath-street, Glasgow. A lecture will be delivered by Professor S. Parker Smith, D.Sc., on "Railway Electrification in Foreign Countries." This will be a joint meeting with the Institution of Mechanical Engineers and the Institution of Locomotive Engineers.

THE INSTITUTION OF WELDING ENGINEERS.—Tuesday, February 12, at 7 p.m., in the Lecture Hall of the Institute of Marine Engineers, 85/8, The Minories, Tower-hill, London. A paper entitled "Some Chemical Aspects of Welding" will be read by Mr. J. R. Booer, B.Sc., F.C.S. A discussion will follow.

INSTITUTION OF PETROLEUM TECHNOLOGISTS.—Tuesday, February 12, at 5.30 p.m., at the Royal Society of Arts, John-street, Adelphi. The following paper will be read:—"Electricity Applied to the Winning of Crude Petroleum with special reference to the Yenangyoung Field, Burma." by Mr. C. H. McCarthy-Jones, M.I.Mech.E., M.I.E.E.

THE INSTITUTE OF METALS. BIRMINGHAM LOCAL SECTION.—Tuesday, February 12, at 7 p.m. in the Chamber of Commerce, New-street. Discussion upon "Waste Products and Losses in the Non-Ferrous Metal Industry."

THE INSTITUTE OF METALS. NORTH EAST COAST LOCAL SECTION.—Wednesday, February 13, at 7.30 p.m., in the Electrical Engineering Lecture Theatre, Armstrong College, Newcastle-on-Tyne. Paper on "Propeller Brass," by Mr. A. Logan.

THE INSTITUTION OF ENGINEERS-IN-CHARGE.—Wednesday, February 13, at 7.30 p.m., at St. Bride Institute, Bride-lane, Fleet-street. A paper will be read by Mr. E. Mudd on "Electrical Breakdowns and Methods of Prevention."

THE INSTITUTION OF CHEMICAL ENGINEERS.—Thursday, February 14, at 8 p.m., at the Engineer's Club, Coventry-street, W., Mr. D. M. Newitt, B.Sc., F.I.C., will read a paper on "The Transport, Storage and Distribution of Hydrochloric Acid, with an account of a complete modern Installation."

THE INSTITUTE OF METALS. LONDON LOCAL SECTION.—Thursday, February 14, at 8 p.m. in the rooms of the Institute of Marine Engineers, 85/88, The Minories, Tower-hill, E.1. Paper on "Metals for Lamp Manufacture," by Mr. W. B. Clarke.

THE INSTITUTION OF ELECTRICAL ENGINEERS.—Thursday, February 14, at 6 p.m., in the Lecture Theatre of the Institution. Joint meeting with the Physical Society. Continuation of discussion on "Loud Speakers for Wireless and other Purposes."

THE OPTICAL SOCIETY.—Thursday, February 14. The annual general meeting will be held at the Imperial College, Imperial Institute-road, South Kensington, at 7.30 p.m. Immediately afterwards an ordinary meeting of the society will be held and the following will be discussed:—"The Additions of Aberrations," by Mr. T. Smith, M.A., F.Inst.P.; "The Choice of Wave-lengths for Achromatism in Telescopes," by Lieut.-Colonel J. W. Gifford, F.R.A.S.; "A New Form of Corneal Microscope," by Mr. E. F. Fincham. Exhibit: By the kind permission of Messrs. Cooke, Troughton and Simms, Limited, and of Colonel H. G. Lyons, F.R.S., Director of the Science Museum, South Kensington, the Troughton dividing engine (1793) will be exhibited, and will be described by Mr. David Baxandall, A.R.C.S.

NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.—Friday, February 15, at Bolbec Hall Newcastle-upon-Tyne. "The Type of Still Engine required for Marine Service, with Special Reference to the Scott-Still Engine," by Mr. W. J. Still.

WEST BROMWICH ENGINEERING SOCIETY.—Friday, February 15, 1924, 7.30 p.m., at the Technical School. Lecture: "The Evolution of Hand Tools," by Mr. Alfred S. Barnes, M.Sc.(Tech.), M.I.E.E.

ROYAL INSTITUTION OF GREAT BRITAIN.—Friday, February 15, at 9 o'clock, a discourse will be delivered by Mr. J. H. Jeans, LL.D., D.Sc., F.R.S., on "The Origin of the Solar System." Afternoon lecture next week: Thursday, February 14, at 5.15 p.m., Sir William Bragg, D.Sc., F.R.S., on "Crystalline Structure of Organic Substances" (Lecture II).

THE JUNIOR INSTITUTION OF ENGINEERS.—Friday, February 15, at 39, Victoria-street, at 7.30 p.m. Ordinary meeting. Hon. member's lecture, "Some Suggestions for Road Transport Development," by Professor D. S. Capper, M.A. (Slides.)

THE INSTITUTE OF METALS. SHEFFIELD LOCAL SECTION.—Friday, February 15, at 7.45 p.m., in the Albany Hotel, Fargate. Conjoint meeting with the Institution of British Foundrymen.

THE INSTITUTE OF METALS. SWANSEA LOCAL SECTION.—Friday, February 15, at 7.15 p.m., in the Metallurgical Department, University College, Singleton Park. Paper on "Fatigue and the Elastic Limit," by Professor Cecil H. Desch, D.Sc., Ph.D., F.R.S.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Coal Trade.—Generally prices are steady, with free supplies of most grades of coal scarce. This was only to be expected in view of the disorganisation caused by the partial strike of locomotive men. The possibility of a dock stoppage in the immediate future has also caused exporters to rush supplies abroad, with the result that most of the collieries are well placed as regards orders, and had only small odd parcels for disposal on the open market. Buyers in the circumstances found it no easy matter to suit their requirements, and the best Admiralty large coals commanded 30*s.*, with seconds around 29*s.*, and the leading Monmouthshires from 27*s.* to 29*s.* Smalls were also steady, the best steam sorts commanding 22*s.* 6*d.*, and other qualities from 17*s.* upwards. Patent fuel, despite the heavy decline in the price of pitch, remained steady at 30*s.* to 32*s.* 6*d.*

Shipping Failures.—Two more Cardiff shipping firms have failed to survive the trade depression, and shareholders in both companies have received intimation that the mortgagees have taken possession of their security—the vessels owned by the companies. The capital loss involves a sum of 135,000*l.*, of which that of the Rumney Steamship Company, Limited, amounted to 105,000*l.* and that of the Lynden Shipping Company, Limited, to 30,000*l.* Both concerns were registered in 1919, and the bank overdraft of the Rumney Company amounted to 77,000*l.* and the loan to the Lynden Company to 24,187*l.* The Rumney Company owned the steamer Rumney of 7,500 tons deadweight, which cost them 180,000*l.* The vessel was sold by the bank for 38,000*l.*, or 142,000*l.* less than the cost four years ago. The Lynden Company owned the steamer Segontian of 1,900 tons deadweight. The position of several other Cardiff concerns is precarious, and it is expected that the list of liquidations is by no means yet complete.

Iron and Steel.—Exports of iron and steel goods last week amounted to 19,956 tons, compared with 13,586 tons in the previous week. Of the total 11,699 tons comprised terneplates and tinplates compared with 6,996 tons; 5,367 tons of blackplates and sheets against 3,567 tons; 1,620 tons of galvanised sheets against 2,225 tons; and 1,270 tons of other iron and steel goods against 798 tons.

CHINESE-BUILT FIRE BOAT.—The Chinese Government Bureau of Economic Information states that Loh Chuen Lan of the Han Dah Motor Company, Shanghai, has built a fire boat. It is 45 ft. in length, 11 ft. in breadth, with a speed of 35 li (about 13 miles) per hour. It is fitted with pumps having a capacity of 400 gallons per minute, the height of delivery being 120 ft. Four hoses can be used simultaneously. The boat is also fitted with a lighting dynamo.

THE INSTITUTION OF ELECTRICAL ENGINEERS: A.M.I.E.E. EXAMINATION.—The next examination will be held on April 3, 4 and 5. Candidates must be either students or graduates of the Institution, or have lodged with the secretary a duly-completed form "E" for election as associate member. Entry forms for the examination, which must be completed and returned by March 1, and particulars regarding election to membership of the Institution, may be had on application to the secretary, The Institution of Electrical Engineers, Savoy Place, Victoria Embankment, W.C.2. The examination is being held this year about a fortnight earlier than in past years in order that those successful candidates who have qualified in other respects for associate membership may be elected before the session is over.

THE LATE MR. FRANCIS JOHN WARING.—We regret to have to announce the death, which occurred on Wednesday, the 6th inst., at his residence, Ealing, of Mr. Francis John Waring, C.M.G., a well-known railway engineer. Mr. Waring went to India at the age of 20, and was engaged on the Indus Valley Railway survey, and, later, on the construction of the Delhi Railway. In 1872, he proceeded to Brazil, where he was also engaged on railway survey work. He entered the service of the Government of Ceylon, as district engineer, in 1875, acting later as chief resident engineer on the survey and construction of railway extensions. Mr. Waring thereafter was appointed acting general manager of the Ceylon Government Railway. He returned to England in 1896, and set up a practice in Westminster, being at the same time railway consulting and inspecting engineer for a number of Colonies and Dominions. Mr. Waring was a Member of the Institution of Civil Engineers, and was awarded a Telford premium and a Crampton prize for two of his papers read before the Institution. He was 80 years of age at the time of his decease.

THE H.I.C. MOTOR TRANSPORT TRAILER.

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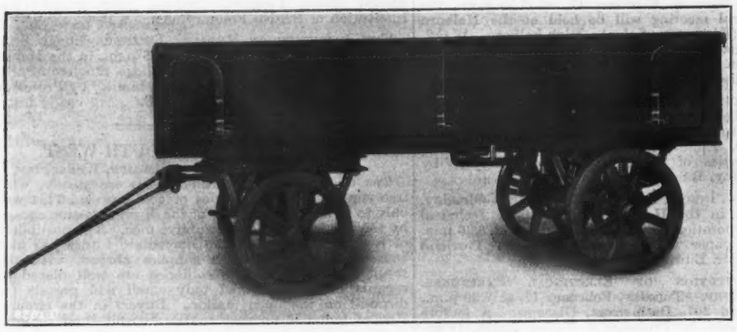
(*For Description, see Page* 186.)



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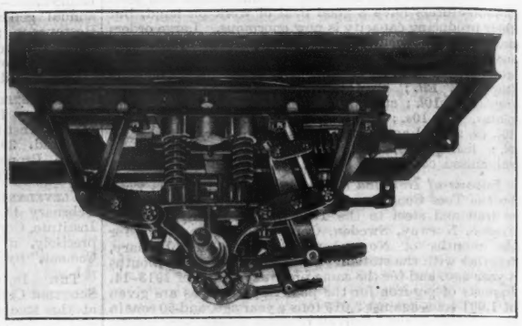

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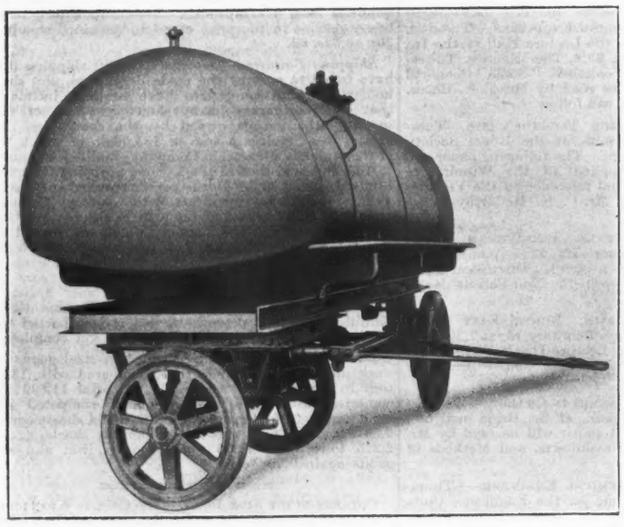

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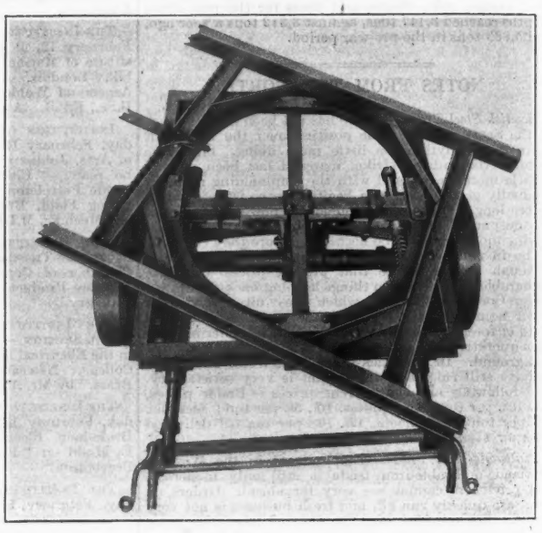

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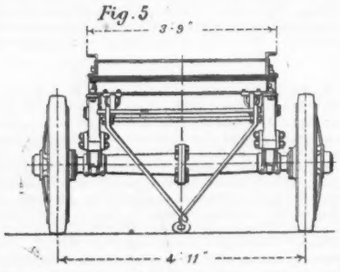

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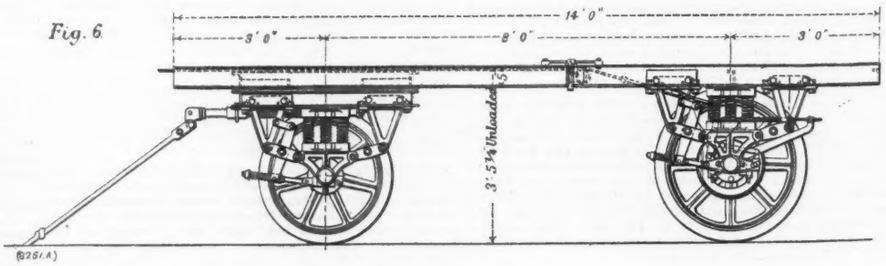
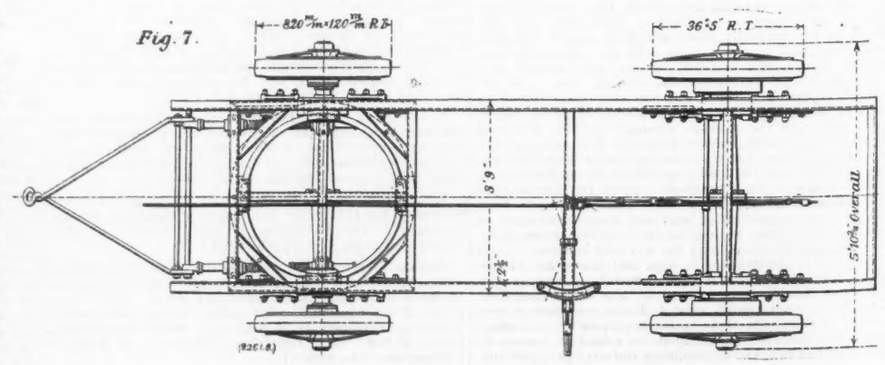


RUSSIA AND THE METRIC SYSTEM.—We read in *Industrial and Engineering Chemist*, Washington, that in order to popularise the metric system, the introduction of which into Russia was provided for by a decree of the Council of Commissaries in 1918, an order has been issued making mandatory the sale of milk in ½, ¼ and 1 litre containers, commencing January 1, 1924, and the sale of products widely used by the population is being organised in standard packets in metric units. The decree was to have become effective on January 1, 1922, but the date was subsequently deferred, on the understanding that the transition to metric weight measures by all State institutions and private organisations and persons should be carried out gradually and completed by January 1, 1927. The electrical industry is to adopt the metric system by November next. Metric units are to be used in all technical plans and specification commencing October 1, 1925, and in all credit and banking accounting, as well as budgetary specifications, after October 1, 1926. The total cost of the introduction of the metric system, including the casting of 30,000 tons of weights, popularisation and instruction, is estimated at 11,200,000 gold roubles.

Fig. 7.



COAL-GAS PLANT WITH DEMPSTER-TOOGOOD CONTINUOUS V

CONSTRUCTED BY MESSRS. ROBERT DEMPSTER AND SONS, L

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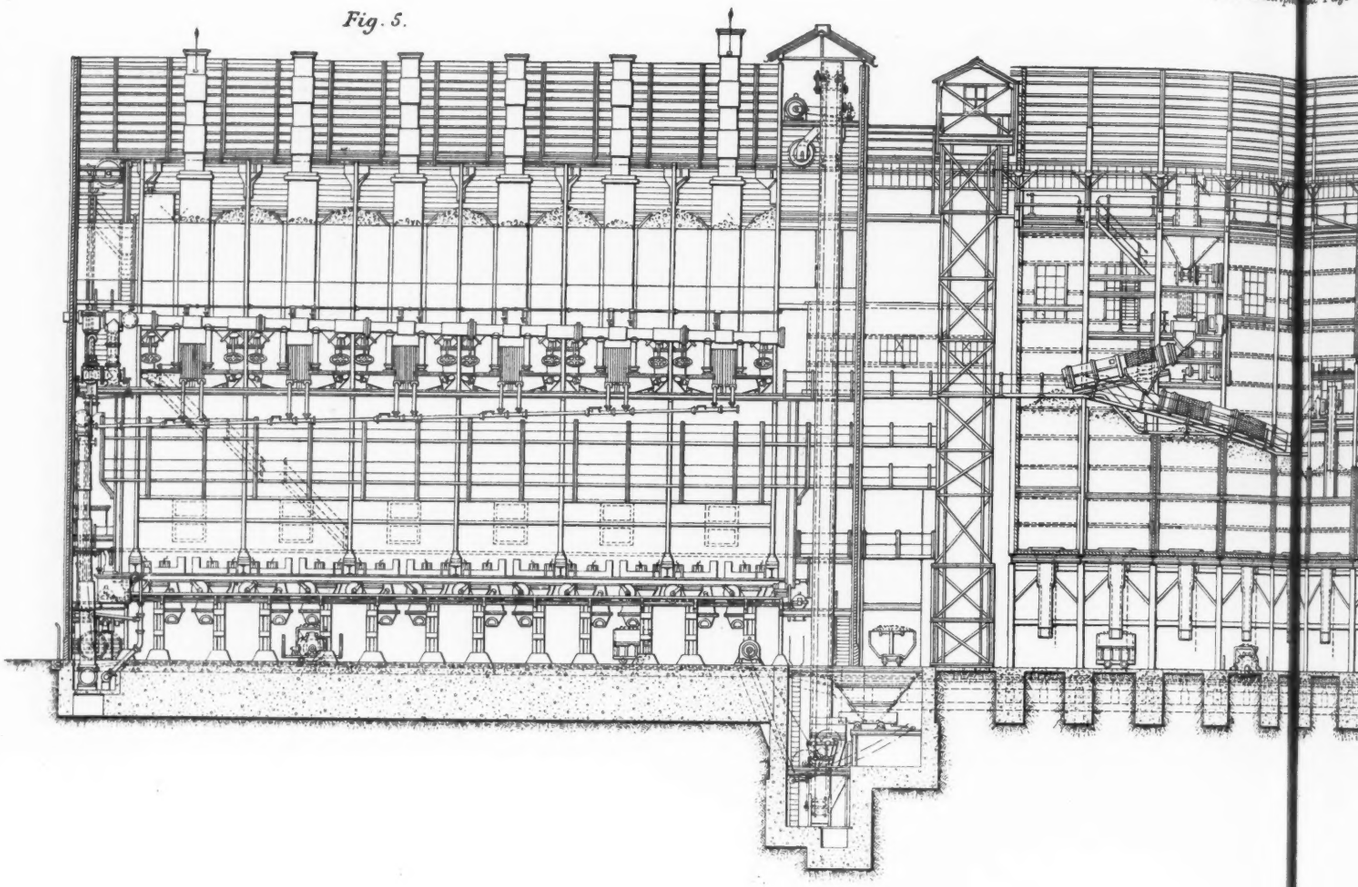

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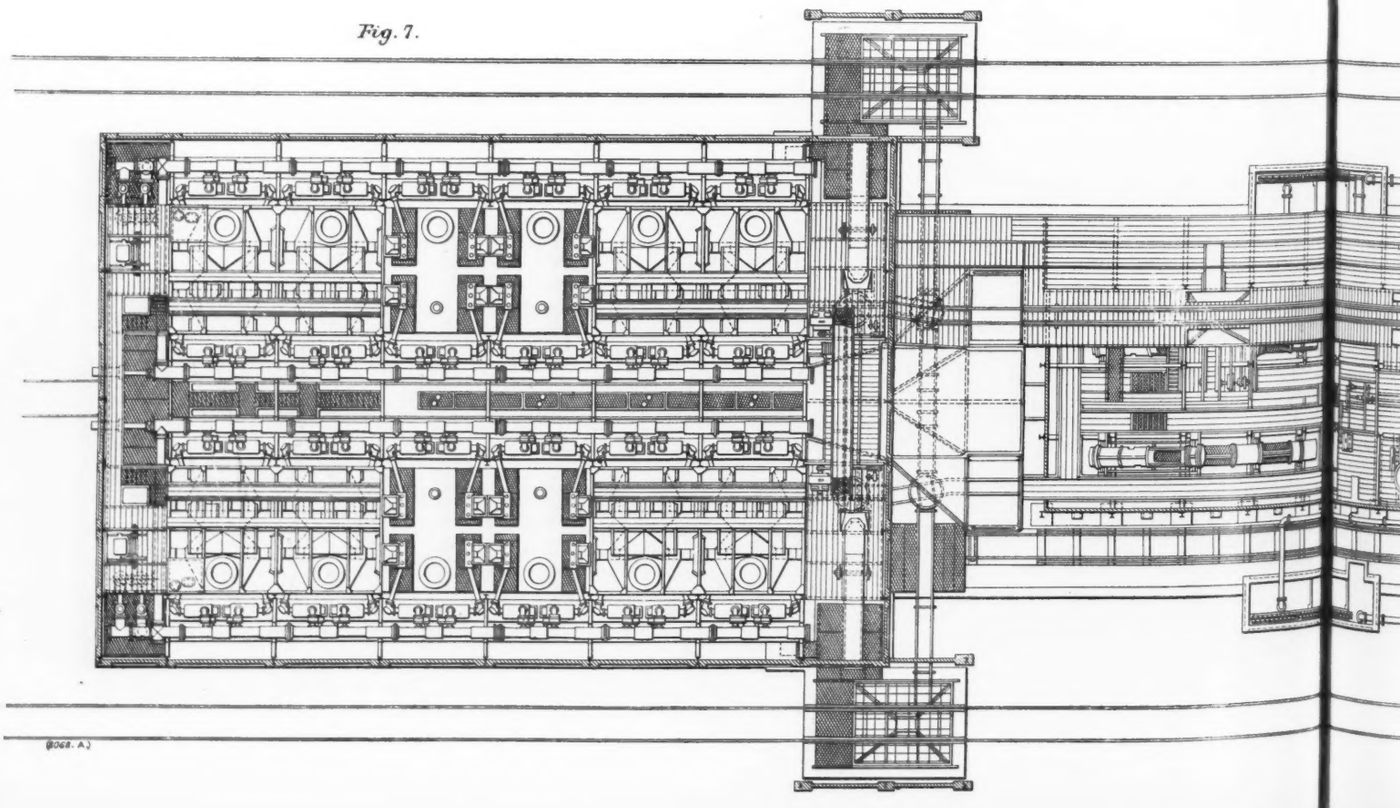

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PSTER AND SONS, LIMITED, ENGINEERS, ELLAND, YORKSHIRE.

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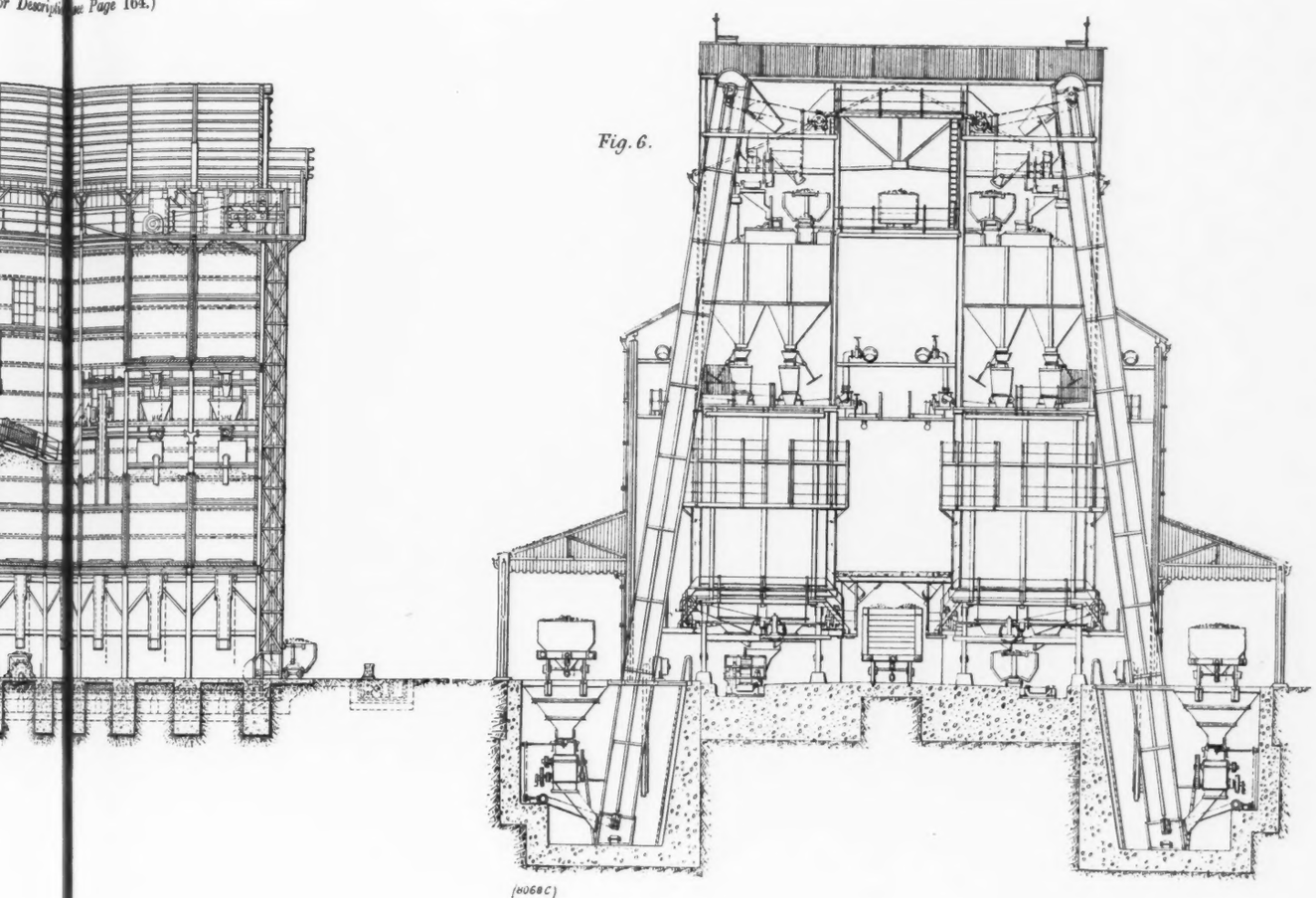

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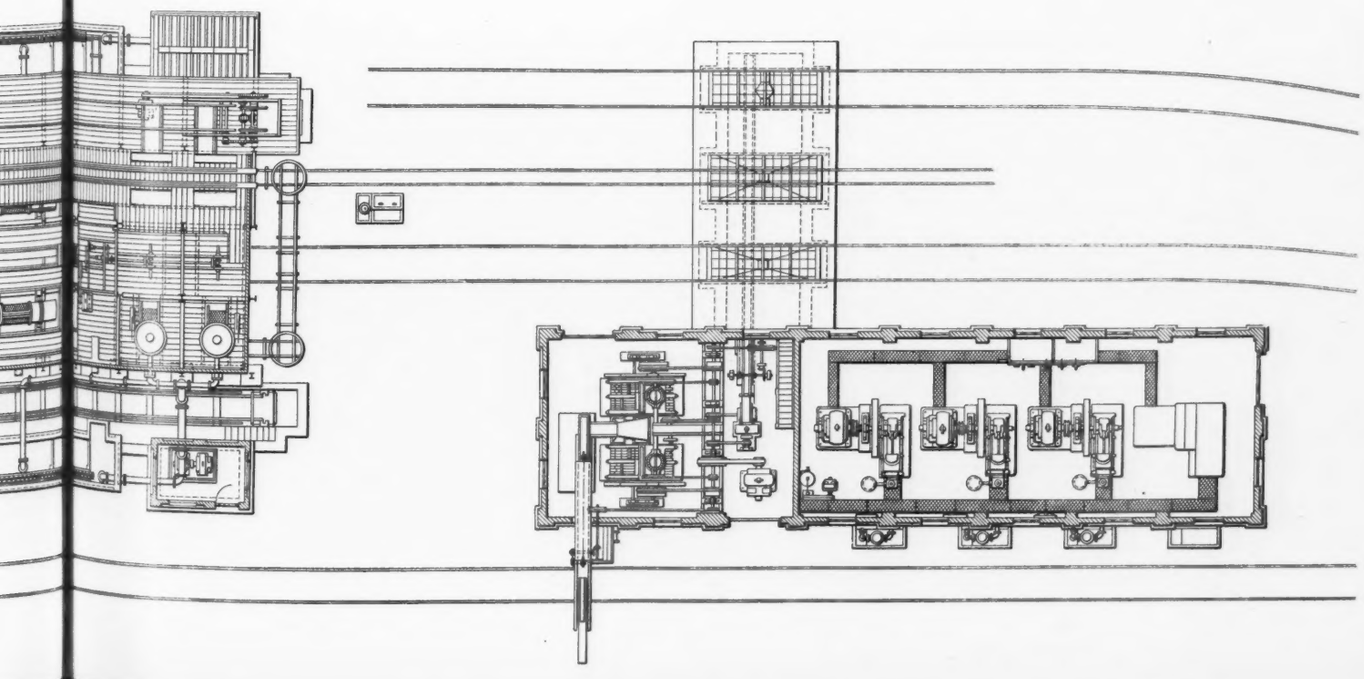

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Advertisements intended for insertion in the current week's issue must be delivered not later than First Post on Thursday. In consequence of the necessity of going to press early with a portion of the edition, alterations for standing advertisements should be received 10 days previous to the day of publication.

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Two-Page Plate.—COAL-GAS PLANT WITH DEMPSTER-TOOGOOD CONTINUOUS VERTICAL RETORTS AT SWINDON RAILWAY WORKS.

ENGINEERING.

FRIDAY, FEBRUARY 8, 1924.

THE SAFETY OF ELECTRICITY IN COAL MINES.

ELECTRICITY is so convenient for lighting, signalling and power-purposes in coal mines that, were there not limits to its use on the score of safety, it would certainly displace all other forms of energy for underground work. It can prove dangerous in two ways, either by producing injury or death by electric shock, or by causing an explosion of a disastrous character. The dangers from electric shock are well understood, and would be no greater underground than on the surface, if the apparatus could be equally well looked after and used with the same degree of care. The dangers from explosion are, however, on an entirely different footing. There is nothing above ground comparable with the conditions 1,000 ft. below, where the atmosphere at any time may be charged with inflammable gas or equally inflammable coal dust. Access to the coal face may involve lengthy journeys along low-roofed roads, often knee-deep in water, and in a darkness which is almost tangible. Along such roads the cables must run, and a spark from a motor, switch, bell or, indeed, from any part of the electric system may, under certain circumstances, precipitate an explosion involving the loss of hundreds of lives. The safe use of electricity obviously depends upon an exact knowledge of what these circumstances are, and Professor W. M. Thornton has been engaged for many years in endeavouring to determine them. The results of his work are of direct practical interest to those concerned either with the safety of mines, or with the design of electrical apparatus for service underground, and some of the conclusions to which he has arrived formed the subject of the paper on "Some Researches on the Safe Use of Electricity in Coal Mines," which he read before the Institution of Electrical Engineers, on January 31.

Most of the accidents in mines have nothing to do with electricity at all, but are of a mechanical nature, and could be largely avoided by better illumination, which would render dangerous conditions more evident, especially along the roads. The imagination of the public, however, generally associates a mining accident with an underground explosion, and finds in electricity a convenient explanation for all sorts of things in the way of fire and explosion, below ground as well as above. Before an electric spark can cause an explosion, two things are necessary. Firstly, the spark must be in free communication with the general atmosphere of the place, and, secondly, this atmosphere must be charged with gas or coal dust to an explosive degree. With modern systems of ventilation gas cannot collect in mixtures rich enough to transmit an explosion throughout the workings. Should a local mixture become ignited, the burst of flame will not extend to any distance, unless the effect of the primary explosion is to throw down coal-dust from the roof and ledges quickly enough to become ignited. If this occurs, the comparatively harmless primary explosion may develop into the much more dangerous and extensive explosion of coal-dust alone, for dust is present throughout the workings.

The most obvious precaution in connection with electricity is to prevent the occurrence of naked sparks, and the Home Office for many years has insisted that all switches should be protected by flame-proof cases. For some reason the sparking at the contacts of electric signalling bells was not considered dangerous, until after the terrible disaster at Senghenydd in 1913, when 439 persons lost their lives. It is not known that the signalling system was responsible on that occasion, but it came under suspicion, and as a consequence provision has now to be made for rendering the spark at bell-contacts harmless. It was shown by Dr. Thornton that the essential feature in gas ignition by break-sparks is some form of ionisation. The voltage across the break is the principal factor in this ionisation, and this voltage is largely due to the inductive rise caused by the sudden rupture of the current. The inductive rise can be suppressed by connecting a resistance in parallel with the bell-coils, thus affording an alternative path to the current when the main circuit is broken. There are other methods of suppressing the spark, and bells can now be made to ring freely in the most explosive mixture of illuminating gas and air—which is much more sensitive to ignition than fire-damp—without exploding it.

Another possible source of danger is the vulnerability of the electric lamp, whether the portable form used by the miners, or the stationary lamp used for general lighting. It has often been assumed that an electric lamp could not cause an explosion if the bulb were broken in an atmosphere of explosive gas, because the filament would be consumed or destroyed before ignition of the gas could take place. This might possibly be true with the ordinary lamps of commerce, but experiments carried out in America have proved most emphatically that the reasoning does not apply to the miniature bulbs working at two volts in the miners' hand lamps. Such lamps have thick and hardy filaments, which will not only last long enough to cause an explosion, but will frequently remain intact for an appreciable time after the explosion has taken place. The United States authorities have, therefore, insisted on the fitting of automatic switches to the lamps, which will cut off the current as soon as the glass is broken or sufficiently cracked to allow the atmosphere to enter. Dr. Thornton exhibited a lamp protected in this way. The bulb contained a pneumatic chamber, which collapsed when air was admitted and operated the switch contacts. A pressure as low as one twenty-fifth of an atmosphere inside the bulb would cause the device to act, and as firedamp cannot be ignited by a hot wire below a pressure of one-third of an atmosphere, there is a very fair margin of safety.

The device, however, which Dr. Thornton preferred on the grounds of simplicity and safety, was one which he had devised to give a danger signal to the miner as soon as the atmosphere in which he was working was of an explosive nature. Any miners' lamp, whether oil or electric, could be fitted with the apparatus, and the worker would be automatically warned to withdraw from the place until the percentage of gas had been reduced to a safe limit by the ventilating system. The action of

the device, which was demonstrated in Dr. Thornton's lecture, depends upon the contact of two metal fingers brought about by the greater heating effect when the lamp is working in an atmosphere containing an undue proportion of gas. The contact of the fingers either gives a visual signal by lighting a small red bulb, or an audible signal by ringing a bell. The ordinary Davy lamp could, of course, be used to indicate gas, by turning the wick down very low and observing the presence of a blue cap to the flame. Doing this, however, involves the risk of losing the light altogether, which is an awkward eventuality as the lamp could only be relit at the lighting station, probably a very long distance off.

Much of the interest of Dr. Thornton's paper lay in the results of his systematic experiments to discover what are the safe limits of current and voltage under which a naked spark may occur in an explosive mixture. The practical bearing of these experiments is in connection with the danger or otherwise when a circuit is interrupted by an accident to the cable. It may be mentioned that experiments carried out on a 3,000-volt, 3-phase paper insulated lead-covered cable with the co-operation of the Newcastle Electric Supply Co., Messrs. Reyrolle and Co., and the Metropolitan Vickers Company, showed that such a cable could be most seriously damaged while alive, without any external flash being observable. The cable in question was connected through a 50-ampere oil switch and a 200-k.v.a. transformer to the busbars of a large substation, so that there was plenty of power behind it. A steel wedge was driven right into the conductors by a blow from a falling weight, but no flash was seen by observers posted for the purpose, and the automatic tripgear operated quickly enough to prevent any signs of burning at the point of damage. From numerous experiments of this kind, it is clear that the risk of sparking when a modern armoured cable is injured by a fall of roof is slight, and even should sparking occur, the chance of the simultaneous presence of an explosive atmosphere is very remote. Were a live cable to be accidentally pulled out of a junction box, a flash would of course occur, but this would take place inside a flame-proof enclosure.

The difference in the effect of direct and alternating current in igniting explosive mixtures of gas is very marked. Dr. Thornton has shown that with continuous current, flowing in a non-inductive circuit at any pressure below 15 volts, it is extremely difficult, if not impossible, for the spark caused by the rupture of the circuit to ignite gas, however great a current may be flowing. As the voltage increases, ignition is caused by lower and lower currents. At 100 volts the current must exceed 1 ampere, at 200 volts, half an ampere, while at very high voltages a current of about one-tenth of an ampere is sufficient. With alternating current the igniting current at any voltage is influenced in a remarkable degree by the frequency. The higher the frequency the safer the spark, particularly at all voltages below 1,000 or so. At 500 volts a direct current of one-fifth of an ampere will cause ignition, but on an alternating circuit of the same voltage, ignition will not occur with less than 11 amperes at a frequency of 100 cycles. At a frequency of only 50 cycles, the ratio of safety is 27 to 1 in favour of the alternating current supply. When the voltage is kept constant, and the frequency alone varied, the current necessary to produce ignition in firedamp increases rapidly with the frequency until about 200 cycles are reached, when it falls off to rise again rapidly at about 400 cycles. This phenomenon is explained by Dr. Thornton on the ionic theory.

The final conclusion drawn from all the experiments on current, voltage and frequency is that alternating current is always safer than direct current when there is little inductance. With power circuits the voltages and currents necessary are such that no real security can be obtained with either alternating or direct current, except by complete enclosure. The currents necessary for lighting or signalling can, however, always be kept within the safety limits, so far as sparks from breaks of circuits are concerned. If alternating current of 15 volts and 160 cycles were used for lighting the roads in the mine, it would require the interruption of a current of not less than 175 amperes to make a spark sufficiently strong to ignite the most explosive mixture possible. The current in any circuit could be easily limited to 175 amperes by an automatic device, and it would be then quite safe to use enclosed replaceable fuses in each lamp fitting and feeder. As regards the lighting of the working face, Dr. Thornton suggests a portable miners' lamp with a double filament. The lamp would work with the usual 2-volt filament supplied by the battery, while it was being carried about. At the working face the base of the lamp would be pressed into socket connected to a 25-volt or 15-volt supply, or to the power supply through a transformer. The other filament would then be switched on, and the lamp would give ten times the light of an ordinary lamp. The current taken by each lamp would be about 1 ampere, and this, at 15 volts, would be less than 1 per cent. of the current which would ignite an explosive mixture by sparking. Safety would appear to be abundantly secured by the proposed method, and there can be little doubt that an increase in the illumination would assist the prevention of mechanical accidents and at the same time facilitate the miners' work.

DEVELOPMENT RAILWAYS.

Apart from strategic questions railways are as a rule planned with either of two objects. They are designed to improve transport in areas already settled, and suggestive of still further industrial development, or they are planned with a view to opening up new areas, the remoteness of which may have offset attractions which they might otherwise offer to mankind. It has fallen to the lot of Great Britain to interest herself in both these directions. At home it is now accepted that we have about reached the limit of economical route mileage, but British capital is to be found abroad interested in countries of all kinds. In India and China for instance, and parts of Africa, British railways have been laid in well populated areas and the improved facilities have resulted in increased productivity, trade and prosperity. In other countries it has been the lot of the railway to act as a pioneering agency. By its means we have peopled waste places of the earth, and in many cases have brought the benefits of peaceful development to lands which had been ruined by internal troubles.

It has always been, and probably will ever continue to be, a moot question as to how such undertakings should be treated. The object immediately in view varies to so great an extent that one is driven to admit that what is suitable in one case may not be desirable or possible in another. We can point to a number of different solutions, all of which have in a manner attained their objects, but it does not follow from this that they would have proved interchangeable, or that any one system would have been applicable to all cases. At home we have an excellent railway system built up in the face of all sorts of difficulties and opposition by private enterprise. In South America private British capital has instituted systems which have greatly assisted in the development of countries of vast distances. In Canada and the United States again, private capital was risked, in this case the hazzard being offset by grants which served the most important end of assisting the railway in the early years of development. Again we find the State itself undertaking the duty of opening up interiors, not always without laying itself open to criticism, but often with no mean success and actuated by motives which private enterprise, compelled to view the situation from a cold blooded financial aspect, could scarcely be expected to harbour. The railways of Australia for instance, in spite of all that can be said of the policies controlling them in the past, have been pushed into the back blocks and have served, as nothing else could have done, to add to the prosperity of the interior and reduce the risks attendant upon a rather remarkable climate. The same policy has been pursued in Africa, where it must be admitted the Government lines have done much to encourage development and trade.

That all has not been well with the railways in tropical Africa will have been gathered from comments made in these columns on some of the reports made on them recently by Lt.-Col. F. D. Hammond, C.B.E., D.S.O., R.E. Lt.-Col. Hammond found many points to criticise, and made suggestions regarding much needed reforms, many having since, we believe, been acted upon by the authorities. This investigation was followed up by a Committee appointed by the Secretary of State for the Colonies, to consider what measures could be taken to encourage private enterprise in the British Dependencies in tropical Africa, especially as regards transportation. The report of this Committee has now been published, the conclusions having been signed by all members of the body but one. The dissentient member, Sir Edwin Stockton, has entered a minority report, which in view of Sir Edwin's standing will certainly commend itself to careful study. We cannot agree, however, with the general tenor of this minority document, which seems to take exception to the somewhat paternal attitude of the Colonial Office with regard to these possessions, and holds that the time has come when commercialism should be the dominating factor in all directions.

In the past it has certainly been the custom of Great Britain in dealing with the backward races of Africa to exercise some protection over the people. The Colonial service as a whole is actuated by ideals which tend to the development of the idea of a trust committed to the hands of officials who in turn endeavour to discharge it honourably. This trust has not been considered to be limited to successful financial administration, and commercialism and exploitation have been secondary to justice and peaceful development. For our part we would not like to see this attitude abandoned, though it might mean some postponement of possible commercial developments. While anxious for everything in the way of efficiency, economy and progress, we would still prefer the paternal Government to purely commercial exploitation. The Dependencies in tropical Africa are not like colonies where whites compete among themselves, and in our view they still require special service.

The majority report of the Committee we have referred to is alive to the fact that State management has not been without defects. It sees little hope of private enterprise taking over the railways of such colonies, and it recommends the commercialism of the state organisation. With this there will be hearty concurrence. General managers should be given freedom and full encouragement to make the lines successful. There should be wider powers as regards staff and business methods. The habit which has grown up of paying any surplus into the general Treasury should be abandoned and any such sums placed instead to the credit of a betterment account. A further suggestion is the creation of railway advisory boards, while a railway inspectorate is proposed for the Colonial Office. The advisory boards would be constituted in the several colonies and would assist the manager on general lines of policy. The inspectorate at the Colonial Office would have direct technical relations with the railways in the dependencies, instead of all matters being passed through the Governor's office.

The chief difficulty in these matters arises from new lines, who should build them and who should stand the loss? The Government reports from Australia are full of tables showing the losses on lines which do not pay. Many of these have been built in the past for political reasons, and without proper investigation of their potentialities. Some in course of time have been abandoned. The tendency now is to take a more commercial attitude and to consider and inquire more closely into prospects, while in some instances the losses incurred on development lines are a matter for compensation to the railway budget. In such areas as tropical Africa the Goverment policy may conceivably render it advisable to construct lines or branches which could not possibly pay at once on a commercial basis. Under a commercial system these would probably not be attempted, but they might be invaluable from the administration point of view.

Clearly, if it is found necessary to combine administration with commerce, the strict business methods to which we are used on railways at home cannot be enforced without some relaxation, or the position of the general managers would be untenable. As to actual construction a considerable contro-

versy has centred round the point as to how this can best be done. If we accept the purely commercial idea we are driven to public tender for all work. If we admit that the colony and its people are held in trust this does not so surely follow. There have been serious extravagancies involved by some of the methods of the past, but it is very doubtful if contracting would remove all the difficulties without introducing others, especially such as concern the supply and management of labour. We are inclined to think that contracting, under, of course, even then suitable government control as regards labour, should be encouraged for large works which cannot well be spread over a term of years, Otherwise we believe the conditions favour a rather lengthy programme, with sections opened as the work proceeds. For small extensions it is doubtful whether large contractors would tender, and it is more than probable that Government could in such cases provide better supervision and direction than a small local firm. Merely to condemn departmental construction for its own sake is to ignore the fact that excellent and economical work has been done on these lines when difficulties have prohibited others. In South Africa where conditions might be expected to favour contracting, departmental construction is in vogue, as it is also in Australasia though usually in the latter not carried out by the railways, a practice which has not, it is true, always proved itself satisfactory from the maintenance point of view. We agree with the majority that cases must be judged individually, with however a preference in our view, where practicable, in favour of the contractor, but we are not prepared to admit that the development of all these Dependencies has reached the stage when commercial matters have only, or even mainly, to be considered.

COLLOIDAL CHEMISTRY.

IN 1861 Thomas Graham distinguished colloidal substances from crystalline materials by the relative rates of their diffusion through membranes, and he believed the distinction between crystalloids and colloids to be fundamental. In introducing his three Cantor lectures, delivered at the Royal Society of Arts, on the last three Mondays, Dr. E. K. Rideal, of Cambridge, stated that this distinction had been shown to be invalid, not only because typical colloids, gold as well as grass fibres, were crystalline, but also because the rate of diffusion of all particles, coarse or microscopic, obeyed the same thermodynamic laws of Einstein and others. The fundamental characteristic of colloidal systems was the property of adsorption, purely a surface effect, which took place whenever a new surface was developed. The many possible variations in interfaces produced by the mutual contacts of phases of gas, immiscible liquids and solids would lead to a great variety of colloidal systems. To make the properties at the interfaces dominant, one phase should be extremely subdivided.

In order to account for the property of adsorption, we had to attribute a certain energy to surfaces. Work had to be done to blow a bubble which took up a spherical form in which it presented the minimum surface compatible with the volume. The surface energy of many liquids had been measured; it ranged, in ergs per square centimetre, from 2 for hydrogen at −252 deg. C., to 75·7 for water at 0 deg., to 750 for silver at 1,060 deg. and to more than 1,500 for platinum at 1,770 deg. Attempts to measure the surface energy of solids by indirect methods had been little successful. The surface energy would be lowered when several small spheres united to one large one, and it could be lowered by adsorption. The addition of a fatty acid to water lowered the tension at the air/liquid interface; the acid, therefore, collected at that interface. Substances increasing the surface tension would move from the surface into the bulk of the solution and a solid would adsorb gases or liquids, or the solute in the latter, if that adsorption would diminish the free surface energy. The effects were thus preferential. Silica gel, Dr. Rideal demonstrated, would adsorb benzene from a mixture of benzene with hydrogen (and from coal gas); charcoal would do the same, and would take salts and dyes out of solutions, and not merely filter them, but it might also adsorb the water by preference, as in the case of sodium nitrate (negative adsorption).

Moreover, the adsorption could not indefinitely be increased by raising concentration or gas pressure. In many cases a saturation maximum was soon attained, at which, it was believed for various reasons, each atom of the adsorbent held one atom of the adsorbate in a film only one molecule deep. When two liquids of surface tensions σ_A and σ_B were brought together, there was a decrease W in the free energy, given by $W = \sigma_A + \sigma_B - \sigma_{AB}$, and that decrease depended upon chemical constitution and affinity. When water was the liquid, compounds containing certain atomic groups, *e.g.*, hydroxyl, the acid carboxyl, were particularly active; with mercury, other groups, such as chlorine, sulphide and again, hydroxyl, were most active. Those groups were evidently the reacting parts which the adsorbing forces attacked by first orientating the approaching molecules.

When a solution of palmitic acid—a waxy crystalline substance, insoluble in water—was poured on water, it spread in a film, the solvent evaporated, and the acid molecules were so orientated that the heavy carboxyl group of the molecule floated on the water, while the rest of the chain-like molecule stood up vertically like a rod. The weight of the acid required to saturate a measurable area of water, the number of acid molecules in that weight and the molecular volume could be determined, and it was thus possible to compute the thickness of the film (which was the length of a molecular chain) and the horizontal cross-section of the molecule. The most recent of these measurements by N. K. Adam, of Cambridge, had been confirmed by X-ray examination. The researches had an important bearing also on the action of catalysts, which could only act when the molecules presented themselves in proper orientation, in which the temporarily-bound molecules were themselves able to react with one another.

In the second lecture, Dr. Rideal dealt with "suspensions" of solids in liquids in which they formed a "sol," or in a gaseous medium, in which they formed a smoke. Suspensions could be produced by various means, for instance, by condensation, precipitating one liquid by another. Whether we then obtained crystals, rapidly or slowly, or viscous jellies depended on the relative concentration and saturation (solubility): Barium sulphate was, broadly speaking, insoluble in water; by varying the conditions, however, P. von Weimarn had obtained barium sulphate crystals in the course of years or of minutes from highly-diluted solutions and jellies at once from concentrated solutions. Heating decreased the surface energy; fine crystals were hence obtained by heating, and the "sintering" of pottery and of metals was similarly explained. Suspensions were also produced by disintegration, mechanical or electrical with the aid of electric arcs between electrodes of the substance, in liquid or gaseous media. The particles produced were in constant Brownian movements and collisions. Why did they not coalesce? Because they carried electric charges, due to their mode of preparation or to the presence of electrolytes, purposely added sometimes to "stabilise" the colloid. The ions were selectively adsorbed, and would prevent or frustrate coagulation, according as they were of the same or of opposite polarity. But "peptising" agents (gelatin, &c.) would likewise be adsorbed preferentially; they prevented the coagulation by coating the particles. According to their charges, the particles would travel with or against the electric current and could thus be separated by electric osmosis or cataphoresis; in the latter case membranes were used which again exerted selective adsorption. The colour of suspensions was not merely a question of size. The particles scattered and transmitted light, and there was, further, an "optical resonance," not well understood; those questions were important for pigments, dyes, enamels and stained glass.

In the third lecture, Dr. Rideal passed to "emulsions," dispersions of one liquid in another. By shaking oil with water, we could obtain an emulsion of oil in water, or of water in oil; the one emulsion could be "inverted" into the other. While the emulsion oil in water was stabilised by sodium oleate (soap), the water-in-oil emulsion was stabilised by calcium oleate; that could be explained by the different active molecular groups and their electric charges and atomic volumes. An emulsion would set to a "gel," more or less solid and elastic. The gel included some of the liquid; sometimes gels formed fibrils, skeletons of rods holding the liquid in their interstices. The gels of some metallic hydrates (aluminium, copper, iron, &c.) were especially rigid; on heating, they became granular. There was thus a gradual transition from the liquid into the solid state. Soap itself, so much used for stabilisation, seemed to stand apart. According to McBain, the soap gel consisted of "micelle," complex colloidal electrolytes of high electric conductivity carrying high electric charges, whilst the ordinary stabilisation and precipitation of colloids could be explained by the assumption of small electric charges, especially when electrolytes of high valency were used. We have, in the present article, had to limit ourselves to indicating the main line of argument of Dr. Rideal's instructive lectures; detailed references to the numerous technical utilisations of colloidal research would have carried us too far.

INTERNATIONAL STUDY OF INDUSTRIAL FATIGUE.

MR. D. R. WILSON'S recently published paper on international co-operation in the study of industrial fatigue is a suggestive and temperate plea for immediate action. He urges that such co-operation would facilitate the collection and examination of work which had already been carried out and of data that might have been overlooked, would co-ordinate the work of existing organisations, and by exhibiting the same occupations under widely different conditions would both help to prevent local influences from being interpreted as general causes of observed results, and provide increased facilities for studying extreme types and conditions of work.

All these contentions may be quite sound, and Mr. Wilson produces instances to support them. Nowadays, too, it does not seem difficult to set some sort of international movement on foot to further any aspiration that is reasonably plausible, and some indeed that are not; so that a suggestion, such as Mr. Wilson's, which is put forward with evident anxiety to take account of practical conditions as well as of unconditioned aspirations, is quite likely to lead to the action it demands. Every one engaged in manufacturing industry will wish it well; but those who have followed what has been done in this country in the study of industrial fatigue will feel that the methods of the study must be revised if the suggested action is to be successful.

At present industrial fatigue is treated as a rule as though it were a branch of applied psychology, or in the alternative as though its operations could be disclosed by merely statistical methods. This view ignores the fact that in most or all industries both fatigue and the output by which it is most commonly measured may be affected as much or more by technical and other circumstances of the individual industry as by psychological and similar factors, and that mere statistics cannot by themselves disentangle the efficient causes of what is observed. The extent to which this view is necessary would be seen more clearly if industrial fatigue were better defined. The most useful definition—though for some reason psychologists have not yet adopted it—seems to be based on the engineer's view of energy as the power of doing work, and expresses fatigue as a condition in which for the time being that power is impaired. In this way it becomes evident that conclusive results can be obtained only when the technical and industrial conditions in which fatigue is developed are studied as exactly as the physiological and psychological circumstances. In the same way, therefore, as psychologists insist that their methods cannot be applied satisfactorily by laymen in their science, satisfactory enquiring into technical and industrial conditions requires the observations to be planned and conducted by scientific men who are competent in the industries concerned.

Until, therefore, this is done habitually the desired progress is not likely to be made, either by

international or any other action. In particular the help of engineers would be needed in the enquiry that Mr. Wilson suggests into what was done in the United States and elsewhere long before the present study of fatigue in this country had begun. Taylor and his school seem to have obtained results far in advance of anything disclosed as the result of work in this country. Unhappily the exposition of their methods often was—still is, for that matter—as bad as the results appeared to be good. What may have been work of the highest value was veiled in a cloud of incoherent verbiage; and what may be the real results of the work can now be ascertained only by enquiry on the spot among the works—if such there be—where the methods were adopted and are continued. Such an enquiry, desirable though it certainly is, would be probably fruitless and certainly devoid of any authority unless made with the help of men qualified by scientific, industrial and technical training.

UNEMPLOYMENT INSURANCE.

It is often thought that British employers are, collectively, strangely mute, notwithstanding the pamphleteering activities of the trade unionists and their Fabian allies; but the National Confederation of Employers' Organisations have removed this reproach—if it be a reproach—by the clear and comprehensive report which they have submitted to the Minister of Labour on the subject of Unemployment Insurance. The report has been made in response to the invitation of Sir Montague Barlow, as Minister of Labour, in November, 1922, to the Confederation to co-operate in considering the steps which might be taken with a view to the establishment of an improved system of unemployment insurance. The invitation was extended also, it is understood, to the Trades Union Congress General Council, but so far that body has not replied.

At the outset of the report the Confederation point out that insurance against unemployment is but one item in the general scheme of social services, and they remind the Minister that the broader problems of the reorganisation of poor law relief and its administration, as well as the co-ordination of all forms of relief of distress, still remain to be undertaken. They say, justly, that the experiment of compulsory unemployment insurance as initiated in 1911 cannot be adjudged a failure; that, on the contrary, experience has proved that it is practicable in normal times to make provision by way of insurance for assisting the *bona fide* workman over periods of temporary and unavoidable unemployment; that it would be unreasonable to expect such a scheme to cope with the stress of a post-war period such as that through which the country is now passing; but that upon an amended scheme of social service, which they say is now long overdue, it should be possible to found State emergency measures which should be free from the confusion and abuses which characterise the administration of unemployment benefit to-day.

From these general considerations the report turns to the vexed question of unemployment insurance by industries. It is interesting to us to observe that most of the questions discussed under this head were raised, if left unanswered, in our article on the subject, of February 23, 1923. The writers of the report consider that little weight should be given to the apparent desire of the Geddes Committee that industries should effect their own unemployment insurance in order that economies may be effected in connection with the employment exchanges. The Committee, they say, did not have regard to the value of a system of employment exchanges in the scheme of social service, nor did they seem to think it mattered that additional expense should be thrown upon employers and workmen, so long as the burden were removed from the State. The writers of the report state, without qualification, that compulsory insurance by industries is impracticable on any comprehensive scale. Among other reasons for this verdict they refer to the difficulty of demarcation between different industries and the administrative difficulties which this would cause; and on the ground of general principle they point out that insurance is founded upon the principle of averaging, the more fortunate helping to carry the less fortunate; that in an industrial country all industry is interdependent; and that, while few, if any, industries can go on prospering indefinitely unaffected by every other, the incidence of depression and unemployment may fall unequally; and they are of opinion that so long as unemployment insurance is voluntary it may be partial and unequal, but if it is to be compulsory it should be universal and uniform. Those engaged in high-risk industries should not be left unaided by the low-risk industries, but the whole industrial population should stand together upon a uniform basis.

In the memorandum which Sir Montague Barlow, issued to the Confederation in November, 1922, it was stated that one of the main objects to be kept in view in any development of unemployment insurance by industries was the linking together as closely as possible of the financial responsibility for paying benefit with the responsibility of finding employment, so as to give the greatest possible incentive for the reduction of unemployment. The writers of the report seem to criticise this when they say that unemployment insurance itself has no meaning as a preventive against unemployment or as an incentive to reduce it. It is, they say, an expedient to make provision for the able and willing worker against a normal risk of industrial life. This is no doubt true so far as it goes, but it seems to touch on a wide question which, in view of the facts as they stand at present, is perhaps somewhat academic, viz., whether unemployment insurance should be treated as something entirely separate from the "machinery" for the notification and filling of vacancies and, generally, the minimising of unemployment, just as the work of the fire insurance companies is carried on more or less independently of the work of the fire brigades. In point of fact, unemployment insurance is administered through the establishments which deal with the notification and filling of vacancies, viz., the Labour Exchanges; and the whole work of the exchanges is carried on by the Ministry of Labour. The connection between the two, therefore, already exists, and it is at least doubtful whether it would be practicable or desirable to sever them. We do not think, however, that the writers of the report intend to suggest that they should be severed, for, later in the report, after referring to the idea of the Royal Commission of 1905-9 that one of the functions of the Labour Department of the Board of Trade (now the Ministry of Labour) should be to act "as a kind of intelligence bureau, watching the continual changing of the labour market and suggesting any measure which may be practical, such as co-ordination and distribution of Government contracts and municipal work so as to act as a counterpoise to the unemployment of the labour market," they say that much of the weakness in the employment exchange administration of unemployment insurance has arisen from the fact that this larger policy has never been developed and matured, and that efficient administration of a national universal and uniform scheme of compulsory insurance is possible only if there is efficient national organisation in the whole field of unemployment, with proper devolution for local requirements, and proper co-ordination with other agencies at work in the social services.

The third part of the report consists of a review of the existing national scheme of compulsory unemployment insurance. The writers consider that the State's contribution to the fund, which was reduced under the 1920 Act to 20 per cent., should be increased to the original amount of 25 per cent. It may be thought that in addition to contributing the 20 per cent., the State pay the cost of the administration of the Act, but this is not so, as the cost comes out of the Unemployment Fund.

The writers of the report are of opinion that the existing refunds to workers under the Acts of 1911 and 1920 should be abolished, as was proposed by the Government in the 1920 Bill. They say that it is anomalous that the worker's premium should be returned to him if the risk against which he insured does not take place. They consider also that the arrangement under which trade unions are allowed to administer the insurance fund tends to keep the skilled men aloof from the employment Exchanges, and that on financial grounds and in the interests of the efficiency and usefulness of the Exchanges as the administrative machinery of the insurance fund, the Exchanges should be the sole administering authority and there should be no concurrent or partial administration by any other organisation. Although they do not go so far as to say that notification by employers to the Exchanges of vacancies at their works should be compulsory, they say there is no reason why employers should not be obliged to intimate to the Exchanges the engagement of workers. This, they consider, would indirectly help the work of the Exchanges by indicating the trend of employment. They endorse the recommendation of the Right Hon. George N. Barnes' Committee of Enquiry of 1920, in favour of special employment exchanges or special departments thereof for particular industries. They acknowledge that the development of exchanges on these specialised lines in large industrial centres would necessitate much better accommodation then is at present at their dispoal, but they say that improved accommodation would permit of greater economy of staff. On the subject of the Labour Exchanges we have a good deal of sympathy with the Ministry of Labour, for they have to try to get the maximum of efficiency with the minimum of expenditure.

In the concluding portion of the report the writers refer to the suggested amalgamation of unemployment insurance with health insurance and other social services. They state that unemployment insurance is not so related, either in principle or in substance, to health insurance, workmen's compensation, or old age pensions as to make amalgamation desirable. It should be administered, in their opinion, as part of a department having under its survey the whole facts of employment, and what is needed is not amalgamation of unemployment insurance with other social services but co-ordination between unemployment iusurance and poor law relief to prevent overlapping and confusion.

It may be anticipated that some of the opinions expressed in the report will lead to a good deal of controversy, but its writers have done good service in reviewing the subject so comprehensively and in drawing public attention to the magnitude of the task of the administration of unemployment insurance and the difficulty of its inherent problems.

NOTES.

College Engineering Societies.

There is one type of engineering society in which a vigorous and healthy activity is almost always manifest. The societies referred to are those composed entirely of men associated in common with the institution where they received their technical instruction. These are not always purely students' societies, for many contain past students of lengthy experience and exceptional attainments. In such societies the young engineer feels more at home than he would in other institutions, in giving expression to his opinions and so forming that valuable and necessary accomplishment of presenting his views with ease, exactitude and power. Where past and present students join together in the work of running these junior institutions, the stabilising effect of the presence of the men of experience, while it does not act to restrict the participation in discussion of the younger members gives the advantage that the faulty deductions of impetuous youth may be corrected in a kindly and happy way. Because of the value that these societies have to young engineers, it is always of interest to take advantage of the privilege of studying the work they are doing. In this respect the University College Engineering Society deserves consideration on many grounds. At the annual dinner, which was held in the College Refectory, under the chairmanship of Professor E. G. Coker, F.R.S., on Friday, February 1, Mr. K. G. Stephenson, in reply to the toast of the Society, proposed by Sir Alexander B. W. Kennedy, told a story of enthusiastic endeavour in which extended membership, largely attended meetings, valuable discussions and the association of the members in successful college and other athletic activity, were the out-

standing features. Sir Dugald Clerk, in thanking the Society for allowing the guests the privilege of learning of their work, showed his appreciation of the good spirit which prevails among the past and present students of the engineering side of a college by referring to his long and happy associations with the Royal Technical College, Glasgow.

BOILER REGULATIONS FOR INDIA.

By the "Indian Boilers Act, 1923," the laws relating to steam boilers in the whole of British India, including British Baluchistan and the Santhal Parganas, have been amended and consolidated, so that uniform regulations now apply over the whole of the area in question. The nature of these regulations is fully set out in a blue book entitled "Indian Boiler Regulations, 1924," which is published by the Government of India Press at Simla at the price of one rupee six annas. Under the Act, no boiler may be operated in India unless it has been tested by a Government inspector, and a certificate issued that it satisfies the new regulations with regard to material, design and construction. It is therefore of the highest importance to boilermakers seeking business in India that they should acquaint themselves with the conditions laid down. These are very explicit, and cover tests of the material used, the formulæ by which the strength of various parts shall be computed, and the practice which shall be followed in respect of various matters. All land boilers and steam pipes come under the Act, although the Government reserve the right to make certain exceptions by order in council, particularly with regard to railway locomotive boilers. Before a boiler is registered by the inspector, a certificate of manufacture, giving certain information on a prescribed form has to be signed by a representative of the makers, and a scale drawing showing details of construction has also to be submitted. In many ways the regulations are similar to those in force in Alberta and other Canadian provinces, and far from being a handicap to British manufacturers they protect our makers from the competition of foreign firms whose standard of design and workmanship and whose ideas of safety are below our own. It is, however, incumbent on our boiler manufacturers to make themselves conversant with the new requirements and to conform with them, unless they wish to find their products excluded from the Indian market, as in certain respects a higher standard is insisted on than is demanded in this country where skilled attendance is available.

A TRADE UNION LITIGATION.

Mr. Justice Shearman's judgment, delivered on January 31, in the case of the Sheet Ironworkers and Light Platers' Society and others *v.* The Boilermakers and Iron and Steel Shipbuilders' Society, dealt with an unusual situation arising from an attempted amalgamation or fusion of the two Societies in 1919. The Sheet Ironworkers' Society had been desirous of being amalgamated with the Boilermakers' Society, and the necessary consent of 50 per cent. of its members had been obtained in accordance with the Trade Union Amalgamation Act, 1917. On the Boilermakers' side there were difficulties in the way of amalgamation, and the requisite consent of 50 per cent. of the members of that Society could not be obtained. The officials of the Sheet Ironworkers' Society eventually were persuaded or agreed to hand over the funds of their Society to the Boilermakers' Society, their members becoming members of the latter Society and the registration of the Sheet Ironworkers' Society being cancelled. Some of the ex-officials and members of the Sheet Ironworkers' Society became dissatisfied as a result of certain disputes, and an attempt was made to resuscitate the Sheet Ironworkers' Society and recover the funds which had been handed over. The old Society was re-registered, and the action was raised for the purpose of having the alleged amalgamation set aside and the funds recovered. Mr. Justice Shearman held that the alleged amalgamation was null and void as not being in conformity with the requirements of the Trade Union Acts, and that the Boilermakers' Society were not entitled to retain the funds delivered to them in 1919. These amounted to 8,469*l*. There still remained, however, the difficulty of knowing to whom the money was to be paid over. It was said for the plaintiffs that the present members of the Society, numbering 150, had elected the present officers, who were plaintiffs in the action; but his Lordship held that they were merely officers of a new union registered in the name of the old one and that the new Society was not the same as the old one. It was also alleged, however, that although the members of the old Society had become members of the Boilermakers' Society, the old Society had never been wound up in accordance with its rules, and his Lordship considered that it continued to exist. Accordingly, he ordered that the funds handed over by the old Society should be paid into Court in order that they might be disposed of by the Court according to the wishes of the members of the old Society. For this purpose the action would need to be transferred from the King's Bench Division to the Chancery Division. As regards the amount to be repaid, the Boilermakers' Society said that they had made disbursements to the members of the Sheet Ironworkers' Society who had joined their Union, but his Lordship held that the funds received must be paid back without any deduction.

RECENT RESEARCH ON CRYSTAL STRUCTURE.

Addressing the Royal Institution last Friday for the first time as Director of the Institution, in succession to Sir James Dewar, Sir William Bragg outlined in his discourse on "Recent Research on Crystal Structure" the X-ray work he has been engaged in and the work now being done in the Davy Faraday Laboratory, which he designated as an integral portion of the Royal Institution. The classical experiments of Laue (1912) had proved, Sir William stated, that X-rays were light waves of 1/10,000 the wave-length of visible light which would therefore be diffracted only by means of the natural gratings formed by the atoms in a crystal. Laue had correctly interpreted his results, but in too mathematical a language. On Sir William's suggestion, his son, Professor W. L. Bragg, had therefore worked out a reflection method of X-ray study of crystal structure. The war had interrupted that work over here, but not abroad. The X-ray analysis had first appeared to be restricted to crystals, but crystals were extraordinarily common, even in leather and cotton, and the crystal did not really represent a special form of matter. The secret of the crystal was the regularity of the array of the molecules, themselves built up of atoms. The reflection of X-rays by crystals was not like ordinary reflection of light. The atoms were supposed to be grouped in parallel planes, each of which would only reflect X-rays at a certain angle of incidence depending upon the spacing of the planes and the wave length used. When we spoke of cubical crystals we imagined the atoms to be spheres closely packed in parallel layers. In metals those planes were planes of easy slip or weakness. A single crystal of copper or aluminium was easily distorted; when we alloyed the copper with aluminium the bigger aluminium atoms replaced copper atoms and prevented slip, thus hardening the metal. The hardening of metals by cold work, first studied in Germany, was now being investigated in the National Physical Laboratory and in the Royal Institution. The hardening was accompanied by a rearrangement of the crystals. Sir William showed some of Faraday's gold foil; it looked yellow in reflected and green in transmitted light; annealed, it appeared almost colourless and bluish respectively, but hardened again by means of agate burnishers, it turned yellow and green once more. Why was that? In the ordinary gold the crystals were arranged at random like the bricks of an irregular pile. Sir William had piled up small wood bricks in a quite irregular heap to exemplify this. When the pile was beaten down, the bricks arranged themselves in planes, all lying flat. The greatest regularity would be obtained when the bricks arranged themselves in alignment. X-ray examination was beginning to explain these structural features. Sir William exhibited X-radiograms of silver, copper, aluminium and steel, all crystallising in the cubical system. All the radiograms showed two lines corresponding to the two principal planes; on hardening the crystal, the one line vanished, the other became stronger; on heating, the latter line disappeared, and other lines appeared. Sir William added that his remarks might seem to contradict Sir George Beilby's theory of the hard and soft states of metals; he had been experimenting with Sir George's specimens, and he only differed by believing the amorphous matter filling up the surface irregularities to be crystalline. He also referred to the importance of molecular orientation on which Dr. Rideal was dwelling in his Cantor lectures on Colloid Chemistry.

LITERATURE.

Sands and Crushed Rocks. Vol. I. *Their Nature, Properties and Treatment* Vol. II. *Their Uses in Industry.* By ALFRED B. SEARLE. London: Frowde and Hodder and Stoughton. [Price 52*s.* 6*d.*]

SAND, says Mr. Searle, is one of the most abundant substances in the world, and since he treats not only of the sand that is the consequence of such constantly disintegrating forces as wind and rain that wear down granite rocks, but is prepared to hasten the operation by artificial means, he attacks a very large subject, demanding the attention of the geologist and the chemist, of the engineer and the metallurgist. The purpose of the book is as wide as the subject, for the aim is to collect and present all the geological, chemical and mineralogical information that is likely to prove of value to those engaged in all the various ways that sands enter into commerce. It is an immense programme, for it embraces the experience of men engaged in very varied occupations, and the scheme must necessarily include many whose connection with sand is remote and obscure.

The author begins at the beginning. He shows the character of the warfare that is everywhere being waged against rock, from the crests of the mountains down to the sea, in all latitudes and in all seasons. In parched deserts as in well watered lands, in the dreary wastes of the frozen north as in the sunny lands of the Equator, disintegration, transportation and decomposition go on without cessation. The weapons of war may seem inadequate, but time is on the side of the attacking force. Insolation is one great agent of destruction. Rain and frost combine their forces to shatter and pulverise all rock-exposed surfaces. The ruin of a past world is necessary for our petty comfort, and therefore we traverse the globe to find the worn *debris* that will minister to our needs most easily and effectively. We visit many countries and listen to a description of the characteristics of each rock from which sands are derived. Generally the mineral constituents of the sand are the same as that of the rock which serves for origin, but such rough generalisations do not satisfy the author, who makes a list of the principal constituents of sand, apart from pure silica, and discusses the occurrence of silicates of calcium and barium compounds and of a long list in which figure metallic and non-metallic elements. The information in this chapter will prove very useful for reference, though naturally the details apply mostly to Great Britain.

From a complete description of the properties of sands the author flinches, and well he may, as sand is not a single mineral of uniform composition, but a heterogeneous mixture into which many components may enter in various proportions, giving rise to products of endless variety which it is convenient to call sand. The plan adopted in face of this difficulty is simple and efficacious. A pure quartzose sand is selected as a standard example, and the changes occasioned by the presence of impurities are traced. Passing over the mineralogical composition and the chemical and physical properties, the remarks on texture are important as they refer to all sands alike, and it seems impossible to frame a definition of sand into which size does not enter. Loose detrital granular matter is not necessarily sand. It may be gravel on one hand or ooze on the other, though this latter may become rock and thence sand in the course of geologic ages. The size of the discreet particles to which the author applies the term sand varies from 0·01 mm. to 2 mm. in diameter on the other: a range of 1 : 200 in linear dimension is a wide limit, and several suggestions beside the obvious one of a sieve of known mesh are made

with the view of increasing the accuracy. The plan of finding a "surface factor," based on the average surface of the particles and depending on the fact that the finer the particles the greater the surface of the whole unit mass, is not without merit, but time consuming in application. A more convenient method is that due to Professor Boswell, in which the limits of grade size are marked off as abscissæ, and the cumulative percentage weight as ordinates, whence graphs may be drawn. In actual practice, however, we imagine the old motto *De minimis* would apply.

This attempt to introduce greater accuracy of measurement and description in the industry raises the whole question of the value of tests, to the conduct of which Mr. Searle devotes an important chapter. He contends that notwithstanding the difficulties experienced in testing and in formulating satisfactory conclusions from the results of such tests, their value is unquestionable, and their acceptance will be more general as the users of sand rely more confidently on the certificates of experts. The chief difficulty, it is stated, is that the most effective tests are beyond the capability of the ordinary user, but that this does not make their use unnecessary. The evidence would have been more convincing if the author had quoted test cases to show that the law courts recognise the validity of tests, and that juries give verdicts in accordance with the rigour of the specifications. For a long time to come, we imagine, the "custom of the trade" will be the deciding factor, rather than scientific accuracy.

To attempt to discuss the methods, or perhaps the intuitions, that guide the prospector in searching for sands, and of plans for mining and quarrying appears to be rather far removed from the main purpose of the treatise, already quoted. To extend the descriptions to embrace the necessary removal of overburden, the lay-out of the mine, the use of explosives, and the decision of such economical questions as the substitution of mechanical for hand labour, overweights the book with unnecessary matter which is better discussed elsewhere. Some of the points are of such an intimate character that each owner or manager must decide for himself, for general formulæ are unavailing. The arguments quoted to decide the policy of replacing hand labour, founded as they are on rigorous arithmetical calculation, may be rendered nugatory by a hostile decision of a trade union, or by the custom of the trade. Where individual decision is the controlling factor, general rules based on average conditions are unavailing.

The processes of crushing of sand rock and of the grinding of sand are more germane to the purpose, and the description of the necessary machinery is sufficiently explanatory to satisfy all but those who have to select the form or modify the existing arrangements of known types. Similarly, with the conduct and treatment of the problems that arise in the management of the sand industry, involving such questions as the purification, or grading, or packing of sand. Those who are unfamiliar with the practical conduct of the trade will learn much, and those entrusted with responsible positions, who have had to overcome difficulties by experience, will find the suggestion of alternative plans useful.

The second volume is eminently practical, but the ground covered or examined is very large. It demonstrates how various are the uses to which sand is put, and how little those who use sand in their own trade know of its uses and requirements in other branches of industry. Sand to the agriculturist, for example, means something very different from what the manufacturer of refractory materials understands by the term, an instance of the inconvenience of using the same word in many senses. Here, however, we have presented a general view of the objects sand serves. Glimpses of many trades are provided which the small angular particles of sand make possible. In the work of brickmaking and building construction, sands are used for moulding, facing, and drying bricks, fulfilling mainly a mechanical purpose. In limestone bricks, the chemical composition becomes of importance, while in connection with crushed rock it is one of the main ingredients of the so-called artificial stone. In concrete and cement, in mortars and plasters, its presence is familiar to all, but the importance of size and texture, the hardness and shape of the grains, and other properties which increase its efficiency are often overlooked, even by those most interested. The construction of water-bound roads and asphalt pavements brings up another set of problems, for road surfaces assume many forms, whose wearing qualities depend greatly on the choice of a suitable sand for the part it has to play.

In metallurgy, the value as the collection of sands again changes. Auriferous sands provide no small proportion of the world's supply of gold, and ferruginous sands are worked for the metallic iron they yield. The dredging of rivers is a source of the tin and platinum that the world needs, and in other instances, the decay of rock into sand facilitates the collection of raw materials. The sand here may be a waste product, but the connection between sand and metals recalls its use in the construction of metallurgical furnaces, furnace linings, and the preparation of refractory bricks of many kinds. In glass-making, in abrasives and polishes, sand largely enters furnishing silica glass on the one hand, invaluable when used for refractory purposes or to withstand sudden changes in temperature, and alkali glass on the other, into which crushed silica rock with soda, potash, and other materials, enter, but sand supplies about 60 per cent. of the total mixture of materials, when melted to form glass. Abrasives are needed more or less in nearly all industries, and here sand may be used in its incoherent form. But all abrasives are of the nature of either natural or artificial sands, though some are not included under this term.

In all these cases and in some others left unmentioned for want of space, sand plays an active part, but in agriculture a different set of problems arises. The sand is a passive agent, it is in the soil, and it is very difficult to add to or to reduce the quantity. It serves the purpose of breaking up the impervious clays that resist the passage of moisture, making drainage easier and more efficient. In filtration, for purifying rivers and producing potable water, sand acts passively but effectively. Substances in solution, and suspended matter are deposited by precipitation, and can be removed by sedimentation or filtration through sand, owing to the coarse matter being held back, giving rise in time to the formation of a bacterial jelly, which stops the passage of pathological bacteria. Mr. Searle touches on so many subjects that his book should be found interesting to a very large class of readers, few of whom will put it down without feeling that he has learnt much.

Friction. By S. E. Stanton, D.Sc., F.R.S., Superintendent of the Engineering Department of the National Physical Laboratory. London: Longmans Green and Co., 1923. [Price 12*s.* 6*d.* net.]

In this treatise Dr. Stanton has covered a very wide field, and collected into a single volume most of what is now known about the friction of solids and fluids. It is common knowledge that the time-honoured experiments of Morin and Coulomb have turned out to be of very limited applicability, and extensive researches have accordingly been made during the last 40 years with a view to further elucidating matters. In some of the more recent of these investigations Dr. Stanton has himself taken a leading part, and with characteristic ingenuity has devised new methods of measurement which have made it possible to obtain accurate observations under conditions of very considerable difficulty. We may note in particular, the apparatus he designed, at the instance of the sub-committee on lubricants for measuring the viscosity of oils at very high pressures.

The opening chapter of the volume deals with the viscosity of fluids both theoretically and experimentally, and includes some notice of Mr. G. I. Taylor's studies of the motion of the atmosphere. In this chapter the equations to the flow of a viscous fluid are established and an attempt is made to explain the connection between viscosity of a gas and the dimensions of its molecules. This particular section, however, is far from lucid, but, fortunately, a reference is given to the original source. In the succeeding chapter Dr. Stanton deals mainly with the line of research originated by Osborne Reynolds, which established the existence of a critical velocity, at which the flow of a fluid through a pipe becomes turbulent. Here, naturally, we find an account of the extremely accurate experiments on pipe friction made by the author in conjunction with Mr. Pannell. These confirmed in a most striking manner the accuracy of the law of comparison predicated by Reynolds, and generalised by the late Lord Rayleigh. Generally speaking the transition from the viscous to the turbulent flow of a fluid appears to take place in a discontinuous fashion, but Dr. Stanton describes some experiments at the N.P.L. with a pipe of $\frac{1}{8}$ in. bore, where a smooth curve could be plotted over the whole of the region of transition. The noteworthy fact is, that in these circumstances, the friction rises to a maximum at an intermediate point, and then falls again as the flow becomes more turbulent. Here, also, will be found an account of Dr. Stanton's important research which gave direct experimental proof of the existence of the film of fluid which creeps in viscous flow along the wall of a pipe. Some of the difficulties met with in using Rayleigh's law of dynamic similarity are also discussed in this chapter. In many cases, the speed of the model which corresponds to the speed of its prototype is impossibly high, and extrapolation has had to be freely resorted to. No mention, however, appears to be made of the ingenious method of surmounting this obstacle, which has been tried in America. By using highly-compressed air in the wind tunnel, these American observers have secured a fluid, the kinematic viscosity of which is very much smaller than that of air at atmospheric pressure.

Lubrication forms the subject of the third chapter, which includes an account of the investigations of Osborne Reynolds, Sommerfeld, and Michell. Attention is drawn here to the curious fact first pointed out by Mr. Harrison that the torque which a bush or brass opposes to the frictional force acting on it, is not exactly equal to the torque applied to the journal. This anomaly arises because in running conditions, the brass and the journal are eccentric to each other and the line of action of the load does not pass through both centres.

In this same chapter, Dr. Stanton also describes the abortive experiments which were attempted at the N.P.L with a complete bush. It was found impossible to obtain any reliable figures with this, but when the attempt was ultimately abandoned and the effective arc of the bush reduced to a few degrees, some very interesting results were obtained, which fully confirmed Reynold's theory. It was further found that lubrication broke down when the film was still four or five thousand molecules thick, an observation which seems hardly reconcilable with the view that the so-called boundary lubrication plays any part in engineering practice.

It is to this question of boundary lubrication that the next chapter of the volume is devoted. What has been established is that under certain conditions other physical properties of the lubricant become of importance besides it viscosity, which alone appears in Osborne Reynolds' formulas. It has, however, to be noted, that, although this is the only physical property of the lubricant which appears in his formulas, Reynolds had to assume other properties in fixing his boundary conditions. So that it is inaccurate to say, as is sometimes done, that viscosity is the only property involved in Reynolds' theory. In establishing his equations Reynolds assumed that there was no slip between the solid boundary and the lubricant. In general, there certainly is none, but it would be a very venturesome extrapolation to assume that this rule holds indefinitely. It seems much more likely if the shearing stress, tending to strip the lubricant away from the solid becomes sufficiently great, slip will occur. In that case other properties than the viscosity of the lubricant are involved in Reynolds' theory.

It has, of course, long been recognised that static friction does depend upon the nature of the surfaces and of the lubricants, but what has not been proven is that any lubrication in the ordinary sense of the term is here involved. The oil film between opposing points of the two surfaces must be extremely thin, since, the surfaces being at rest, all lubricant which is not actually anchored to the solid surfaces must be squeezed out. Hence the layer of lubricant at these opposing points is presumably only one or two molecules thick. It, then, seems incredible that an oil film only one

or two molecules thick should "wear" well enough to enable lubrication to be permanently maintained. One would rather anticipate that the relatively large amount of work expended on this very thin film, when motion occurs, would destroy it by the heating effects produced even if the stress involved it did not tear it free. Moreover, some experiments described by Mr. Hardy and Miss Doubleday in *Nature*, in February, 1923, showed that a time factor was involved, which certainly suggests that surface tension was at work gradually accumulating surplus lubricant into aggregations round the high parts of the opposing surfaces, a condition which would inevitably lead on subsequent motion to "hydro-dynamic" lubrication on Osborne Reynoid's system. This, it should be stated, is not the explanation of their observations which is advanced by the observers in question. They hold that the effect represented the time required for the molecules of the film to orient themselves, but in view of the rapidity of the thermal agitation, it would be natural to expect that orientation would be an almost instantaneous phenomenon.

The concluding chapters of Dr. Stanton's book deal with the frictional stability of earth and similar problems, with ball-bearings, and with the connection which Osborne Reynolds established between the frictional loss in a pipe and the rate of heat transmission between the pipe and the fluid passing through it.

As will be seen, the field covered is a very wide one, and it will prove a very great convenience to many, to have thus brought together matter which has hitherto been accessible only in scattered papers. The ample references to original articles and authorities, moreover, will be very welcome to those who wish to study special points in greater detail.

The Chemical Resistance of Engineering Materials. By MARSTON LOVELL HAMLIN and FRANCIS MILLS TURNER, J.R. New York: The Chemical Catalog Company, Inc. [Price 5 dols.]

THE authors of this book have collected and classified within the 177 text and 69 appendix pages important data on the behaviour of the material from which chemical plant is usually constructed. The title of the book is perhaps to this extent slightly misleading, as many important engineering materials, which do not happen to enter into the construction of chemical plant, are either not mentioned or receive but scant treatment. Chemical plant was, so evidently in the minds of the authors that the book is subdivided according to the chemical in contact with the materials, and not primarily according to the materials.

The first aim of the authors—as stated in the preface—to present the available information fully and quantitatively, is well realised, in view of the difficulty of dealing with such a wide field within the limits of a comparatively small book. The collected data are well arranged; the tabulated summaries of trials are a valuable feature. The information contained in the book is certainly worthy of a more extensive index.

The pages allotted to atmospheric and sea water corrosion are devoted to data obtained from various series of technological experiments. Much of it will be useful to engineers. No discussion of current theories is attempted; the extremely important matter of the corrosion of power plant condenser tubing is hardly touched upon. The rustless group of alloy steels receives some treatment. References are made both to the 12 per cent. chromium steel, extensively used in this country, and which is now available in various degrees of hardness; also to the quaternary alloys containing both nickel and chromium. The latter possess perhaps an even wider range of applicability.

Protective coatings for ferrous metals receive scant treatment. These are of great importance and interest to engineers. Metal spraying will take an increasingly important part in this domain, as experience with the process accumulates. Further impetus may be given, if and when a satisfactory electrical spraying pistol is evolved.

The resistance of stellite is considered, and more should be heard of this most interesting alloy.

Monel metal is fully and satisfactorily discussed. This material is becoming more widely adopted, and in addition to its chemical resistance it can be prepared with a wide range of excellent mechanical properties. Monel metal castings now provide a simple solution to many previously difficult problems.

The resistance of metals and alloys in contact with gases at high pressures and also high temperatures is touched on. The compressed gas industry, which has now attained very considerable dimensions, with its requirements of plant and bottles renders the question important. A convenient method of protecting the interior of gas cylinders has yet to be evolved. The present tendency to use lighter and thinner bottles renders a solution of this question of internal pitting more necessary than ever. Metal spraying seems a promising possibility here. The modern synthetic ammonia processes demand materials to stand high temperatures as well as pressures. It may eventually prove possible to evolve a material which will, in addition to compliance with the foregoing demands, also serve as catalyst, and be capable of electric heating. The tendency in turbine design to increase the initial temperatures, and possibly employ working fluids other than steam brings an attendant train of problems: so also do gas erosion and corrosion, in the internal-combustion engine. The gas turbine awaits material resistant chemically and mechanically at the temperatures and pressures involved in the suggested cycles.

The second aim of the authors was to provide a bibliography of the subject by giving reference to all the sources used. Nearly 200 references are given. It seems a strange omission that no reference to either *Stahl und Eisen* or *Revue de Metallurgie* can be traced. These are among the most important journals dealing with engineering materials, and many valuable contributions dealing with the newer materials have appeared in these papers.

There are a few minor typographical errors, and misspelling of foreign words which will doubtless be remedied in future editions.

The appendix, on properties of materials and useful constants, is a valuable feature of the book.

It is difficult to say to what extent the third aim of the authors will be realised. This is avowedly to stimulate work in unexplored fields, and suggest such presentation of experience as shall render it of more immediate application. The insistent call for the quantitative expression of conditions, and notation at any rate, of factors, which cannot at present be expressed quantitatively, is of prime importance and cannot be re-emphasised. But could not these lacunæ in data be at least surveyed, if the scientific spirit were brought to bear more penetratingly on the facts already accumulated?

The book cannot fail to be extremely valuable to a very wide circle of readers. The technological matter will be directly useful to engineers, metallurgists, chemists and architects. The authors are to be congratulated on its compilation. It is thought that the value of future editions will be increased if greater space be devoted to the more "theoretical" aspects of the problems presented and explanations tendered.

BOOKS RECEIVED.

Hydraulics. A Text-Book for Students and Engineers. By ERNEST H. SPRAGUE, A.M.Inst.C.E. Second revised and enlarged edition. London: Scott, Greenwood and Son. [Price 8*s.* 6*d.* net.]

Aeronautical Research Committee. Reports and Memoranda. No. 797. *On the Rate of Transmission of Heat from the Walls of an Airship Passenger Car.* By Miss DOROTHY MARSHALL, B.Sc. [Price 6*d.* net.] No. 819. *On the Determination of the Stresses in Braced Frameworks.* Part IV. *The Effects of Axial Loading, Flexure, Torsion and Shear upon a Tubular Framework with Taper.* By R. V. SOUTHWELL. [Price 6*d.* net.] No. 831. *On the Effect of Sideslip on the Aerodynamic Forces and Moments (including those due to the Controls) for a model S.E.5a Aeroplane.* By H. B. Irving, B.Sc., and A. S. Batson, B.Sc. [Price 1*s.* net.] No. 855. *Some Suggestions for Improving Aeroplane Control at Low Speeds.* By A FAGE, A.R.C.Sc. [Price 6*d.* net.] No. 856. *Some Experiments on a Model Biplane having Slotted Wings, with Particular Reference to the Improvement of Lateral Control at Low Speeds.* By H. B. IRVING and A. S. BATSON, B.Sc. [Price 6*d.* net.] No. 858. *The Resistance of a Spheroid, with Special Reference to the Effect of Wires placed around the Model in a Plane at Right Angles to the Axis.* By R. JONES, M.A., and A. H. BELL. [Price 6*d.* net.] London: His Majesty's Stationery Office.

Department of Overseas Trade. Report on the Economic and Financial Conditions in Mexico, October, 1923. By NORMAN KING. London: His Majesty's Stationery Office. [Price 1*s.* net.]

Elementary Principles of Reinforced Concrete Construction. A Text-Book for the Use of Engineers and Students, &c. By EWART S. ANDREWS, B.Sc. Third revised edition. London: Scott, Greenwood and Son. [Price 7*s.* 6*d.* net.]

United States Bureau of Labour Statistics. Bulletin No. 341. *Trade Agreement in Silk Ribbon Industry of New York City.* By MARGARET GADSBY. Washington: Government Printing Office. [Price 15 cents.]

Commissariato Dell'Aeronautica. Intendenza Generale. Notiziario di Aeronautica. No. 1. *Gennaio*, 1924. *Note Techniche di Aeronautica, Gennaio*, 1924. Rome: Tipografia Della R. Accademia Nazionale dei Lincei.

Hydro-Electric Power Stations. By DAVID B. RUSHMORE and ERIC A. LOF. Second edition, revised and reset. New York: John Wiley and Sons, Inc.; London: Chapman and Hall, Ltd. [Price 37*s.* 6*d.* net.]

Moving Pictures: How They are Made and Worked. By FREDERICK A. TALBOT. Entirely rewritten. London: William Heinemann, Ltd. [Price 10*s.* 6*d.* net.]

Department of Overseas Trade. Report on the Trade and Commerce of East Africa (Uganda Protectorate, Kenya Colony and Protectorate, the Tanganyika Territory and the Zanzibar Protectorate), June, 1923, revised to September, 1923. By COL. W. H. FRANKLIN, C.B.E., D.S.O. London: His Majesty's Stationery Office. [Price 1*s.* 6*d.* net.]

Steels' Tables. Useful Tables and Formulæ for the Iron, Steel and Metal Trades. Compiled by JOSEPH STEEL. London: Sir Isaac Pitman and Sons, Limited. [Price 3*s.* 6*d.* net.]

The Subject-Index to Periodicals 1920. *K Science and Technology.* Issued by the Library Association. London: The Library Association. [Price £1 5*s.* net.]

South Wales Coal Buyers' Handbook. By WILLIAM PHILLIPS. Cardiff: William Phillips. [Price 10*s.*]

Department of Overseas Trade. Report on the Economical, Financial and Commercial Conditions in the Dominican Republic. By DARRELL WILSON. *And in the Republic of Hayti, September*, 1923. By J. E. M. CARVELL. London: His Majesty's Stationery Office. [Price 1*s.* 6*d.* net.]

Imperial Institute. Monographs on Mineral Resources, with Special Reference to the British Empire. Vanadium Ores. By Members of the Scientific and Technical Staff of the Imperial Institute. London: John Murray. [Price 5*s.* net.]

Flugzeugbaukunde. Eine Einführung in die Flugtechnik. By Dr.-Ing. H. G. BADER. Berlin: Julius Springer. [Price 1·15 dols.]

Die Kraftstellwerke. Part I.—Die Elektrischen Stellwerke. By S. SCHEIBER. Berlin and Leipzig: Walter de Gruyter and Co. [Price 1·25 mark.]

La Télégraphie Sans Fil. Ses Applications en Temps de Paix et pendant la Guerre. By JULIEN VERDIER. Paris: Gauthier-Villars et Cie. [Price 35 francs.]

The Calculus of Observations. A Treatise on Numerical Mathematics. By E. T. WHITTAKER, Sc.D., and G. ROBINSON, M.A., B.Sc. London: Blackie and Son. [Price 18*s.* net.]

United States Bureau of Labour Statistics. Bulletin No. 348. *Wages and Hours of Labour in the Automobile Industry*, 1922. Washington: Government Printing Office. [Price 10 cents.]

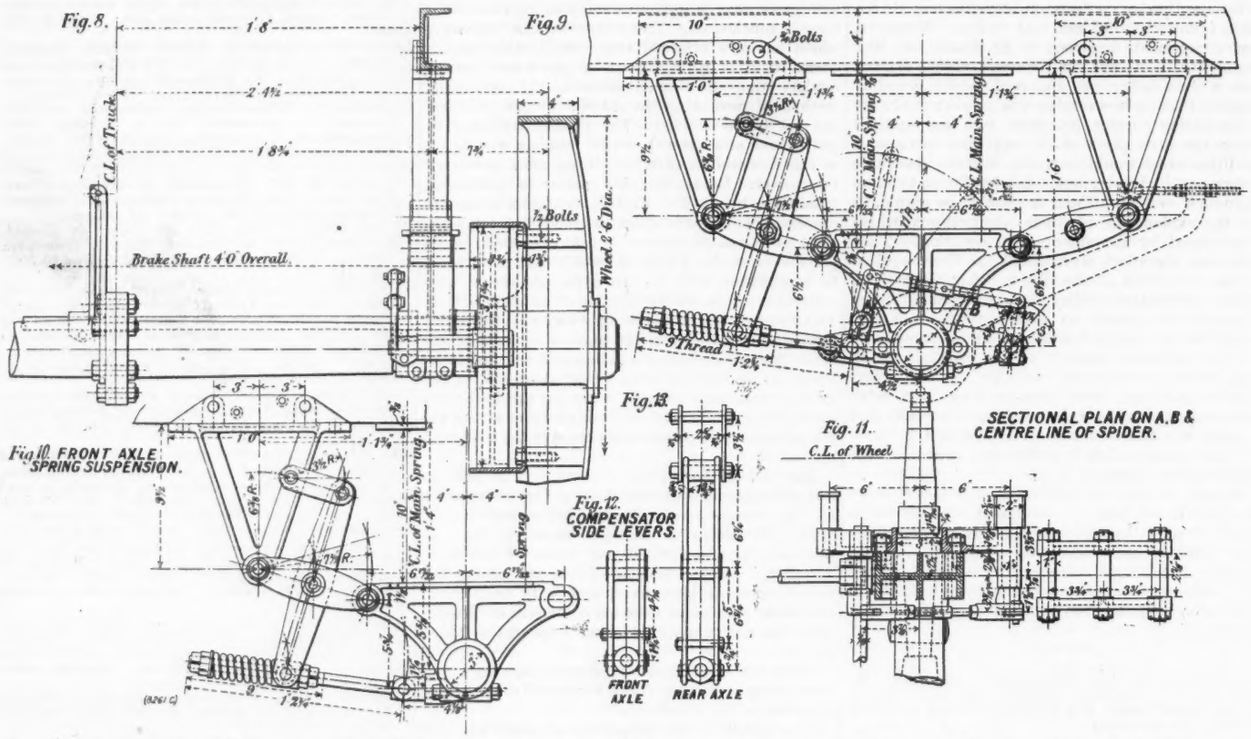
The Staffordshire Iron and Steel Institute. Proceedings. Vol. XXXVII. *Session* 1922–23. Walsall: Offices of the Institute.

INSTITUTION OF NAVAL ARCHITECTS.—The annual general meetings of this institution will take place on Wednesday, April 9 and the two following days, in the Lecture Hall of the Royal United Service Institution, Whitehall, W.C.2. The annual dinner will be given on Wednesday, April 9, at 7.30 p.m. in the Grand Hall, Connaught Rooms, Great Queen Street, Kingsway.

THE LATE PROFESSOR QUINCKE.—With Professor Quincke, who died at Heidelberg on January 12, in his 90th year, has passed away one of the few remaining links with the great scientists of the middle of the last century. George Hermann Quincke was born at Frankfurt-on-the-Oder on November 11, 1839, studied at Königsberg, Berlin and Heidelberg, and took his Ph.D. degree at Berlin in 1858, where he afterwards lectured on Physics. By 1872 he was Professor at Würzburg, and in 1875 he was called to Heidelberg where he spent most of his later time, and where he died. He did not write any books, but the range of his scientific work was very wide. One of his first papers was geophysical, but he soon made a speciality of the problems of capillarity and molecular forces and invisible films. His researches on soap bubbles, on which he reported to the British Association in 1884, on vortex motion, on the transport of particles by the electric current, on the electrification of liquids forced through membranes, and on other electric problems, on magnetometers and on volume changes by magnetism, &c., were often quoted. He also constructed an acoustical thermometer, and wrote on refraction and polarisation and the optical properties of metals, as well as later on Becquerel rays and radium. He was one of those gifted men who can take accurate measurements with the simplest apparatus made up of a match-box and rubber tubing. Of a genial disposition and always ready to assist, he was very popular. Together with M. Planck and E. Warburg he was one of the curators of the Annalen der Physik, to which he contributed his last paper a few years ago, up to his death. The Physical Society of London elected him an honorary Fellow in 1882.

DETAILS OF THE H.I.C. MOTOR TRANSPORT TRAILER.

CONSTRUCTED BY MESSRS. HAULAGE IMPROVEMENTS AND CONSTRUCTIONS, LIMITED, ENGINEERS, LONDON.



THE primary economic considerations in the road transport of goods are the amount that can be dealt with and the distance this can be conveyed in a given time by the equipment available. To increase the volume of goods that can be carried, endeavours have been made at various times to separate the functions of motor haulage and carrying, by using a mechanically-propelled vehicle in the same way as a horse, for the purpose of drawing, and having trailers for the accommodation of the load. Such an arrangment has many advantages over a mechanically-propelled vehicle carrying the whole of its load, having to be then designed to withstand the load effects due to its own weight and that of the goods. The magnitude of the shocks which have to be resisted is, of course, dependent on the speed of travel and the surface conditions of the road. To meet these excessive weight would be necessary, and its introduction can only be avoided by measures which lead to an increase in the repair bills.

It is for this reason and to avoid the necessity for the motor standing idle during the time of loading and unloading that many engineers consider that the only way to reduce road transport costs is to keep the load off the tractor and distribute it over one or more trailers. With these aims in view Messrs. Haulage Improvements and Constructions, Limited, of Granville House, Arundel Street, Strand, London, have designed a transport truck which has the additional advantage of shock reduction through exceptional springing. Road shock losses are very great with the usual construction of trailer, and the endeavour to diminish them in this case has taken the lines of improved spring suspension of the wheels to ensure that the direct shock of the wheel against the side of a hole in the road is replaced by the action of rolling up the small steep face of that rise, as the wheel is given a certain amount of spring-controlled movement in the horizontal direction. Further reduction of shocks to the tractor unit is made possible by the use of an elastic attachment between the motor and trailer. This takes the form of a well-sprung triangle. The illustrations above and on page 178 show the details of construction of the H.I.C. trailer as well as its application to some of its many fields of service. Fig. 1 shows a general service truck, while Fig. 3 shows a fuel oil tank trailer and indicates the free movement which is permitted by the turntable fore-carriage.

As will be seen from Fig. 2, the axle is housed in completely spring-suspended rigging. Vertical loads are taken by the upright springs but the lever systems allow certain freedom of movement against the action of the spring beside the axle. Actually, the illustration, Fig. 2, shows the draught gear as well as the spring suspension. Just under the frame are seen the two horizontal arms with ends having provision for connection to the draw bar. These arms are provided with springs which are put in either tension or compression to suit the requirements. When turning a corner, the bar on the inner side of the bend will be pushed inwards and its spring put into tension, while at the other side compression is operative. This spring draw bar system has the advantage that sudden jolts at starting and stopping are avoided, and a reduction of wear and tear on the motor unit may, therefore, be expected. The turntable, better seen in Fig. 4, is not of the usual type, but is arranged to give a larger area of support for the distribution of the load.

With the combination of the spring-controlled draught gear and the free turntable, the tracking of the trailer is ensured under all conditions of operation. A complete chassis for a 4–5-ton transport truck is shown in Figs. 5 to 7, while the details of the rear axle and brake gear are given in Figs. 8 to 13. The brake can be put into action by means of a hand lever, in the cab of the tractor, which is connected to the wire rope system, or from the road by means of a side lever, on the trailer. The general arrangement of this system is clearly shown in the general drawings of the trailer, Figs. 5 and 6. Demonstrations which we have witnessed showed the easy starting obtainable when this trailer is in use, and the freedom from shock to the goods on the trailer and also to the motor-propelling unit.

THE DETERMINATION OF VISCOSITY.—A recent publication of the British Engineering Standards Association, bearing the number 188—1923, contains the specification for the British standard method of determining the viscosity of a liquid in C.G.S. units, and its object is to provide simple and accurate means for making such measurements which will be suitable for commercial application. The specification gives standard dimensions for viscometers of the U-tube, co-axial bulb, and falling-sphere types, and describes the methods of using and calibrating these instruments in detail. It also deals with the method of determining the viscosity of opaque liquids by means of the Lidstone viscometer, as well as by the adaptation of the U-tube and falling-sphere viscometers. Plates illustrating the form of all the viscometers mentioned above are included in the specification, which is obtainable from the offices of the Association at 28, Victoria-street, Westminster, S.W. 1. Its price is 1*s.* net, or 1*s.* 2*d.* post free.

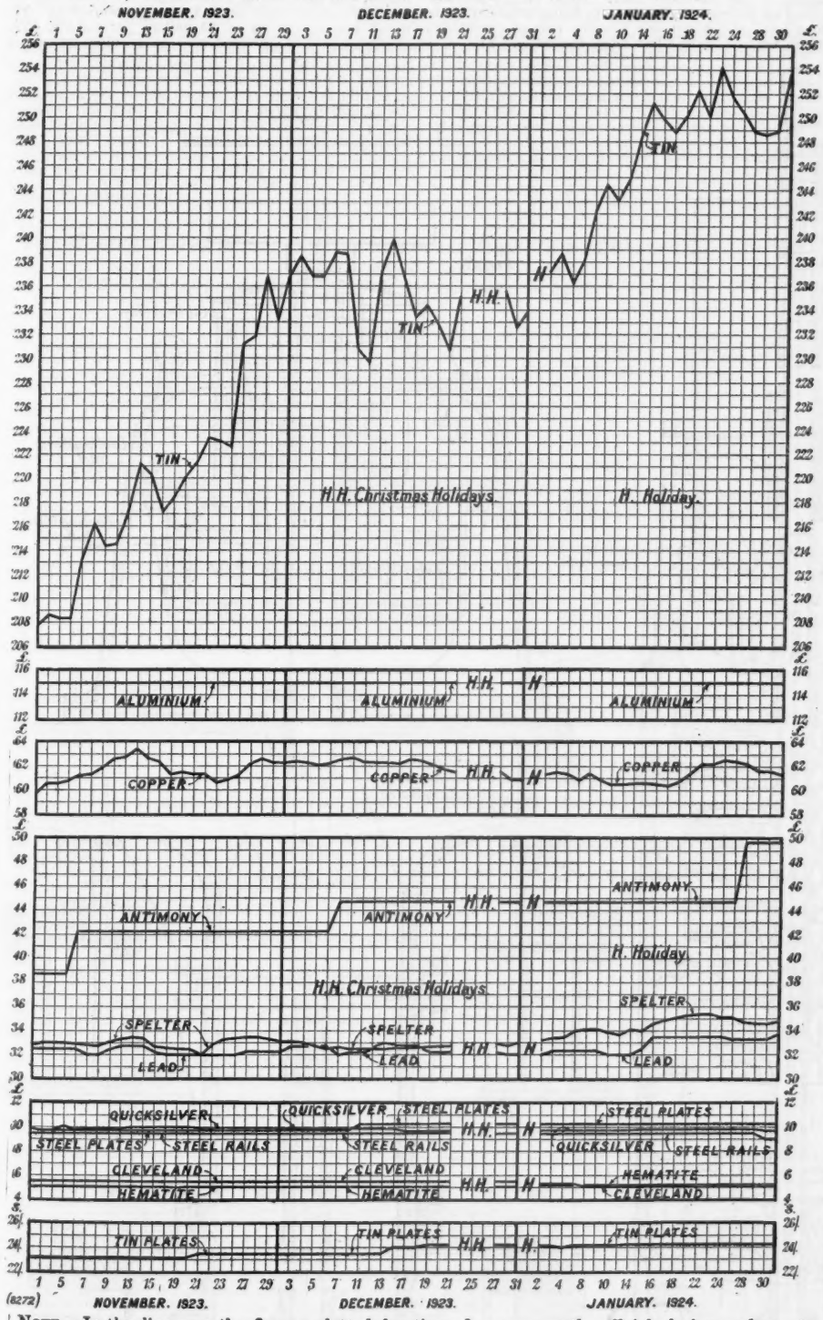
DEVELOPMENTS IN BOILER FIRING WITH PULVERISED FUEL.

WE understand that the Union d'Electricité has placed another large order for pulverised fuel plant with a company which is associated with Messrs. Vickers and International Combustion Engineering, Limited, 4, Central Buildings, London, S.W.1. The plant is to be installed at the Gennevilliers power station, near Paris, which is now supplied with steam power by Babcock and Wilcox and Stirling boilers having multiple-retort and chain-grate stokers. For the extension now required it has been decided to install four boilers of the Ladd-Belleville type with Lopulco plant for pulverised fuel firing, the boilers each having 19,500 sq. ft. of heating surface and being capable of supplying 150,000 lb. of steam per hour at a pressure of 440 lb. per square inch when working at full load. The boilers will have an overload capacity of 240,000 lb. of steam for two hours, this being rendered possible by the use of pulverised fuel. These guarantee figures, it may be mentioned, have been based on fuels of widely-varying characteristics, one containing 11 per cent. of ash and 17 per cent. of volatiles, and the other 20 per cent. of ash and 8 per cent. of volatiles. The pulverised-fuel plant will include eight Lopulco gravity coal driers, eight Raymond roller mills each grinding 6 tons of coal per hour, and 48 Lopulco variable-speed feeders and burners of the fish-tail pattern. The same company has a similar contract in hand for the Vitry power station of the Union d'Electricité, and has also received a contract to equip the new power plant of the Société Metallurgique de Hoboken, near Antwerp, with boilers arranged for firing with pulverised coal on the Lopulco system. Another order recently placed in Belgium for such plant was for the equipment of a power station at Charbonnages de Beeringen, in Limbourg.

THE SUPPORT OF POLES CARRYING OVERHEAD WIRES.—In order to avoid the trouble caused by the rotting of telegraph and other poles at the ground-line, the Clark-Williams Engineering Company, of Bridgeport, Connecticut have introduced a new method of supporting such poles. A concrete base is provided, the top of which is well above the surface of the ground and carries two strong angle-brackets of malleable iron. These brackets are held to the concrete by bolts passing through slotted holes in the feet of the brackets, so that the latter are adjustable. The pole is clamped between the brackets by strap bolts which surround its butt, the latter being held quite clear of the concrete base, and exposed to the air at all times. Poles supported in this way may obviously be many feet shorter than when the butts are buried, and their life is said to be at least four times as long. The renewal of poles, moreover, is easy, and the rigidity of the brackets is often sufficiently great to dispense with guys which would otherwise be needed.

DIAGRAMS OF THREE MONTHS' FLUCTUATIONS IN PRICES OF METALS.

(Specially Compiled from Official Reports of London Metal Markets.)



NOTE.—In the diagrams the figures plotted for tin and copper are the official closing cash quotations of the London Metal Exchange for fine "foreign" and "standard" metal respectively. The prices shown for lead are for English metal, whilst those for spelter are for American metal. Middlesbrough prices are plotted for steel plates and rails, and also for hematite and Cleveland pig-iron. The prices given, in the case of steel plates are for ship, bridge and tank qualities, and those for steel rails are for heavy sections. The pig-iron prices are for East Coast hematite and Cleveland iron, both of No. 1 quality and for home consumption. The price of quicksilver is per bottle, the contents of which vary from 70 lbs. to 80 lbs. The price of tin-plates is per box of I.C. cokes f.o.b. at Welsh ports, but in other cases the prices are per ton. Each vertical line in the diagram represents a market-day, and the horizontal lines represent 1*l.* each, except in the case of the diagram relating to tin-plates, where they represent 1*s.* each.

THE HINDLEY VERTICAL BOILER.—With reference to our description of the Hindley vertical boiler, on page 121 *ante*, we are informed by the makers, Messrs. E. S. Hindley and Sons, of Bourton, Dorset, that the test which showed a superheat of 48 deg., was made on a boiler without a superheater fitted, the superheat being obtained by the effect of the upper portion of the tubes passing through the steam space. The firm claim the ability to superheat steam in contact with water without a superheater as a very important feature of the boiler. We are informed that with normal firing and no superheater, the steam is superheated by 30 deg. F., while when a superheater is fitted, a superheat of at least 100 deg. F. is obtained.

THE SOMERFORD PUMPING STATION, SOUTH STAFFORDSHIRE WATERWORKS COMPANY.*

By FREDERIC JOHN DIXON, M.Inst.C.E.

(Concluded from page 157.)

IT will be noted that this pump is to lift from 150/210 ft. below ground level, and also it must fulfil similar conditions as regards continuous working and quantities delivered when lowered to pump from a depth of 300 ft. This borehole has an artesian head of about 16 ft. 5 in., and, after considering the data relating to the yield obtained during the pumping test, it was decided to install the pump at a depth of 210 ft. below ground level (see Fig. 7). Should the water level be permanently lowered the pump will be extended down to the 300 ft. level. The pump is of the vertical-spindle multi-stage turbine type (Fig. 8), arranged for six double inlet self-balancing impellers, working in series, but at the present time only five impellers are actually fitted, and a dummy stage is inserted to suit the lower specified head. The impellers and guide passages are in bronze, and the overflow of distance pieces containing the passages for directing the flow of water to the various stages are in cast iron. At the delivery end of the pump is a hydraulic balancing piston, which is capable of taking practically the whole of the weight of the rotating parts when the pump is running. The water which leaks past the balancing piston is piped back to the suction side of the pump. The steel impeller shaft of the pump is entirely cased in gunmetal, and the two pump bearings are water-lubricated. Two lengths of suction pipe and a foot valve are fitted, and above the foot valve is a release valve operated by a wire cable from the surface to empty the pump if, at any time, it should be found necessary to draw it out of the borehole.

The borehole delivery pipes from which the pump is suspended, and the rods forming the driving shaft, are all made to one standard length. The pipes are flanged, and at each joint is inserted a shaft guide bearing. This guide bearing is spigoted into both flanges to secure accurate alignment. The actual bearing consists of a lignum vitæ sleeve with water lubrication grooves, which is carried in a gunmetal sleeve secured to the centre boss of the casting. Radial ribs join this portion to the outer spigotted rim, which is secured by the flanges. The coupling boxes connecting the several lengths of shafting are made of steel. Each rod end is coned, and the drive is transmitted by sunk keys. The boxes are secured to the rods by split collars, and screwed gunmetal nuts provided with lock-nuts. The whole of the pump work is suspended from a headbox carried on built-up steel girders, and the delivery branch of the borehole pump is embodied in this casting. From this casting a connection is taken to the overhead cooling water tank.

Mounted on top of the headbox is a thrust bearing which supports the whole of the rotating elements, and at the same time accurately locates the pump impellers in relation to the guide wheels or passages. This thrust bearing is of the multi-collar type, fitted with a forced lubrication system which is water-cooled, Fig. 9. The water-cooling connection is taken from the headbox. Immediately above the thrust bearing is the flexible coupling which transmits the drive from the gear box. The gear box is carried on another set of steel girders immediately over the thrust bearing and headbox. The gear is of the Citroën double-helical bevel type, running in oil, having a gear-increasing ratio of 1 to 3·58. The lubricating arrangement for this gear box is also water-cooled, the water supply being again taken from the headbox. The vertical shaft bearing is of the collar type, and the horizontal shaft bearings are of the ring-lubricated type. The borehole pump does not discharge into a tank at the surface, as is the usual practice with steam plant, but delivers direct to the suction branch of the force pump. A sluice valve and non-return valve are fitted in these pipe connections, the latter being inserted to prevent the reservoir pressure coming back on the borehole pump and foot valve when the plant is standing. The borehole pump is so designed that it delivers the water at the surface under a pressure, thus giving a suction head on the force pump. A compressed-air recording depth gauge is connected to the borehole, and this registers on a weekly chart the level of the water below engine-house floor.

The force pump is of the belt-driven horizontal turbine type, having five single inlet impellers working in series. The impellers and guide passages are in bronze and the distance pieces between the stages in cast iron. At the delivery end of the pump a hydraulic balancing device of the disc type is fitted, the overflow water from which (included in the pump efficiency), instead of being led back into the well and wasted, is carried to the cooling water tank of the engine. A make-up connection to this tank is also provided from the headbox of the borehole pump, the pressure in which is always sufficient to ensure the supply. Very little make-up water is required. The impeller shaft is supported in two oil ring-lubricated bearings carried by the end covers. The driving pulley is mounted separately on two similar bearings to relieve the pump of any belt strain, and the drive is by means of a pin and buffer type flexible coupling, which is fitted with screw disengaging gear so that the engine can be run without the pump for trial purposes. The belt drive from the engine flywheel to the pump pulley has an increasing ratio of 1 to 4·75 and is fitted with a "Lenix" belt-tightening gear, which considerably increases the arc of belt contact on the driving pulley, thus giving a better driving effect, and

* Abstract of paper read before the Institution of Water Engineers, London, on December 11, 1923.

reduces the belt strain on the bearings. The gear arrangement consists of two fulcrum arms passing over the driving pulley and carrying a jockey pulley which runs on the outer surface of the belt. The weight of this jockey pulley tends to tighten the belt, but, in addition, levers and balance weights are fitted to the fulcrum arms and the required tension is obtained by adjusting the position of the balance weights. In order to damp down vibration due to inequalities in belt thickness and surging of the belt, the two balance levers are fitted with oil dashpots. The force pump delivery branch is fitted with a non-return valve and a sluice valve before connecting to the pumping main, and both valves are fitted with by-passes for priming. A venturi meter and pressure recorder are fixed in the engine-house, and the venturi tube is placed in the pumping main quite close to the engine-house. At the opposite side of the belt drive a 6 kw. direct-current generator is fixed, which will be dealt with under the auxiliaries. A tachometer, driven from the force pump shaft, shows the speed of the pump. By means of the hand-adjusting device on the governor the engine speed can be regulated until the desired pump speed is obtained to give the quantity of water required.

Two discarded egg-ended boilers in good condition were purchased and lowered into the basement on completion of the basement floor. These boilers are supported on concrete stools, the tops being arranged at the same level to prevent any possible risk of overflowing if one tank is being filled from the other. The oil is fed into both tanks at the bottom through a special mounting which was fitted. Each mounting carries an inlet connection projecting about 1 ft. above the bottom of the tank, which also serves as a fuel pump suction connection, the projection preventing sediment and water which settles in the bottom being drawn into the pump. A test cock and drain connection are also fitted. A receiving tank is placed outside the building at ground level, and the road wagon discharges the oil directly into this through a filter. A pipe from the receiving tank is led to both storage tanks, the necessary controlling valves being fitted to divert the oil into either tank as may be desired. The fuel pump can draw from either of these tanks, and connections are provided so that the oil can be pumped out of one tank into the other if necessary. The fuel pump is of the horizontal single-stage centrifugal type, direct-coupled to an electric motor, and lifts the oil from the storage tanks into the overhead supply tank carried over the workshop. The pump has a capacity of 25 gallons per minute. The overhead tank is provided with an overflow connection which leads back to the storage tanks in case the attendant does not stop the pump when the tank is full. The overhead tank supplies the service tanks in the engine-room. These tanks are provided with ball valves, which maintain the oil at a constant level, ensuring an efficient supply to the engine.

The engine-room is served by an overhead crane having a lifting capacity of 24 tons and capable of lifting the whole borehole pump or the heaviest portions of the engine. To provide power for the overhead crane auxiliary pumps and lighting, a vertical single-cylinder four-cycle Diesel engine of the semi-open type of 25 b.h.p.

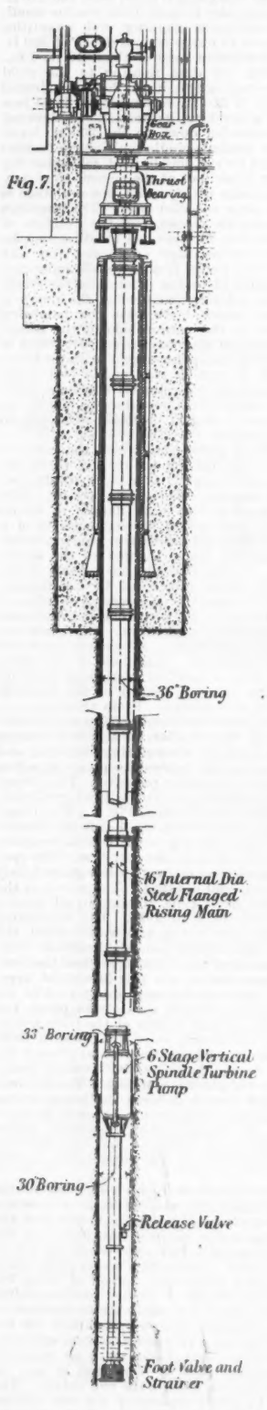
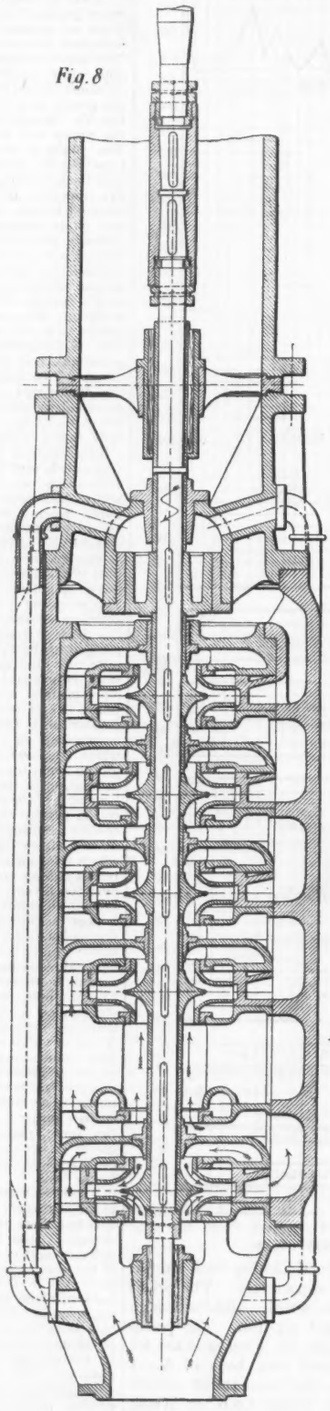
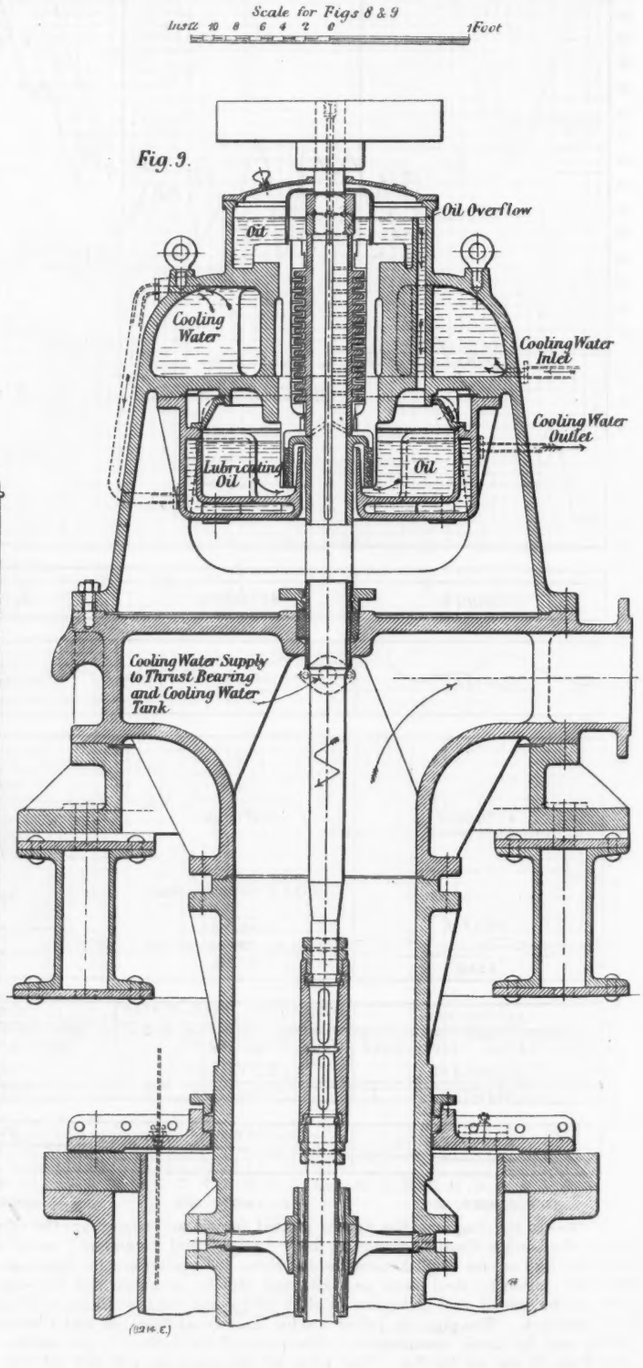


Fig. 8



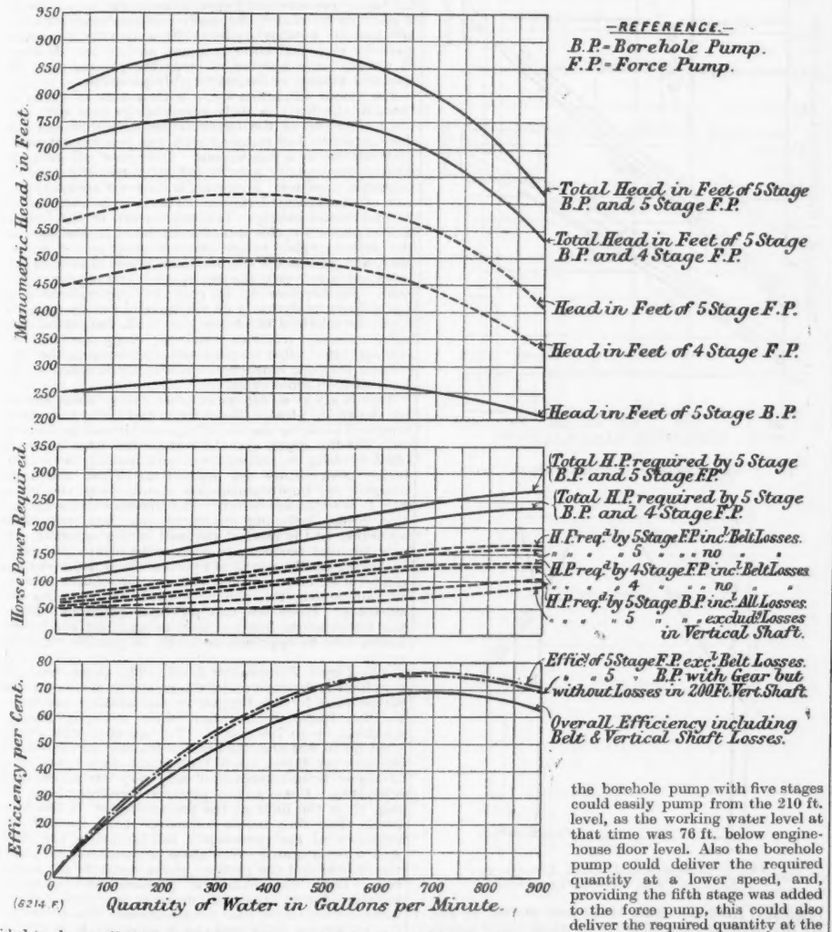


is installed, and this drives a 15 kw. compound-wound open protected type direct-current generator working at 220 volts from the flywheel by means of a belt drive. The construction of the engine is on similar lines to the main engine except that the air compressor, being placed behind the power cylinder, is driven by means of a rocking lever and links from the engine crosshead. The current is led to a main switchboard and distributed from there. The power required for the crane made the installation of a unit of this size necessary. It was, however, decided this was too large and expensive to run for lighting purposes under normal conditions. A 6 kw. unit was, therefore, provided and fixed on the force pump bedplate, as previously mentioned. This is driven by means of a "Benn" coupling, which can be thrown in and out of gear whilst the force pump is running. The air bottles of the main engine and the auxiliary generating set are interconnected so that one set can be charged from the other. In addition, an auxiliary air compressor is provided to charge all the bottles if required. This consists of a single-cylinder two-cycle hot-bulb oil engine of 2/3 b.h.p., with a two-stage compressor driven from the engine crankshaft. This unit is capable of giving a maximum compression of 1,200 lb. per square inch when running at 650 r.p.m., and can draw a maximum of 210 cubic feet of free air per hour.

Somerford pumping station is at the extreme end of a main having a total length of 29,920 yards. From Somerford to Slade Heath, a distance of 4,000 yards, the main is 18 in. diameter, whilst the remainder is 24 in. diameter. This main is to convey two million gallons per day from Somerford and two million gallons from Slade Heath, and the friction heads for the respective stations were calculated on this basis. Only the Somerford plant is at present in operation, and the frictional head is, therefore, considerably reduced below that specified. If reciprocating pumps had been installed it would have been necessary to run at the contract speed to give the specified quantity, whilst the efficiency would fall appreciably below that guaranteed due to the low load factor of the prime mover. With the turbine pumps installed it is possible to maintain efficiently the same rate of discharge over a considerable range of head by speed variation. Also at any constant speed the quantity discharged will vary according to the head, a lower head than normal giving a greater quantity and a higher head a lesser quantity. At the same time, the Diesel engine has a considerable range of speed and power over which it can work efficiently. These characteristics of the engine and pumps have been utilised to advantage to meet the prevailing conditions, as will now be described.

The borehole pump is designed for six stages to pump from 300 ft. below the engine-house floor, but, as previously mentioned, it is now working with five stages to pump from the 210 ft. level. The force pump is designed to do the specified work with five stages. In view of the reduced head it was decided as an experiment to fit only four stages, and run the engine at its specified speed of 300 r.p.m. When working under these conditions it was necessary to run with the force pump discharge throttled, making an artificial head, as otherwise the quantity discharged would have been considerably in excess of requirements. At the same time, it was noted the borehole pump was delivering the water to the force pumps at a head of 220 ft. This demonstrated the borehole pump with five stages could easily pump from the 210 ft. level, as the working water level at that time was 76 ft. below engine-house floor level. Also the borehole pump could deliver the required quantity at a lower speed, and, providing the fifth stage was added to the force pump, this could also deliver the required quantity at the reduced head. The results of the series of tests on the two pumps alone and in combination are shown on the graphs in Fig. 10.

Fig. 10. REVOLUTIONS PER MINUTE OF BOREHOLE PUMP = 1020 CONSTANT.
" " " " FORCE PUMP = 1340 "
CORRESPONDING REVS. PER MIN. OF ENGINE = 285 "


—REFERENCE.—
B.P.-Borehole Pump.
F.P.-Force Pump.
Manometric Head in Feet.
Total Head in Feet of 5 Stage B.P. and 5 Stage F.P.
Total Head in Feet of 5 Stage B.P. and 4 Stage F.P.
Head in Feet of 5 Stage F.P.
Head in Feet of 4 Stage F.P.
Head in Feet of 5 Stage B.P.
Horse Power Required.
Total H.P. required by 5 Stage B.P. and 5 Stage F.P.
Total H.P. required by 5 Stage B.P. and 4 Stage F.P.
H.P. req.d by 5 Stage F.P. incl. Belt Losses.
" " " 5 " " no " "
H.P. req.d by 4 Stage F.P. incl. Belt Losses
" " " 4 " " no " "
H.P. req.d by 5 Stage B.P. incl. All Losses
" " " 5 " " excl.ve Losses in Vertical Shaft.
Efficiency per Cent.
Effic.y of 5 Stage F.P. excl. Belt Losses.
" " 5 " B.P. with Gear but without Losses in 200 Ft. Vert. Shaft.
Overall Efficiency including Belt & Vertical Shaft Losses.
Quantity of Water in Gallons per Minute.
(6214 F.)

The running costs for the month of August are given below, and it may be stated that, although the plant has to be started up daily, the fuel consumption is only slightly more than that obtained at the trial on a continuous run under working conditions for which the plant was built:—

Running Cost for August, 1923.

Total gallons pumped	.. .. ..	17,387,840
Average total head in feet	.. .. ..	518
Equivalent thousands of gallons 100 ft.	..	90,065
Weight of fuel oil used, in tons	.. ..	14·328
Weight of paraffin for starting, in tons	..	0·178
Total cost of fuel oil	..	75*l.* 7*s.*
Labour charges for month	..	38*l.* 14*s.* 11*d.*
Lubricating oils used, in gallons	.. ..	35·5
Cost of lubricating oils	..	4*l.* 19*s.* 11¼*d.*
Cost of stores	..	18*s.* 7½*d.*
		Pence.
Cost of fuel oil per 1,000 gallons, 100 ft.	..	0·2007
Labour " "	..	0·1032
Lubricating oils " "	..	0·0133
Stores " "	..	0·0024
Total running cost per 1,000 gallons, 100 ft.		0·3196

At the present time the plant is not required to run continuously, and a stoppage is made every month for the purpose of cleaning.

The cost of the works, which partly provides for duplication of the plant, was 32,926*l.* The contractor for the engines and pumps, including all piping, were Messrs. Sulzer Bros., of London and Winterthur, Switzerland; the electric equipment, Messrs. The Electric Construction Company, of Wolverhampton; the electric crane, Messrs. James Carrick and Sons, of Edinburgh; the borehole, Messrs. A. C. Potter and Co., of Grantham; and the buildings, Messrs. T. Lowe and Sons, of Burton-upon-Trent.

THE MARGINS OF POSSIBLE IMPROVEMENT IN THE CENTRAL STATION STEAM PLANT.*

By ERNEST L. ROBINSON, Schenectady, N.Y.

MANY influences are tending to force manufacturers of power to use the greatest care in the lay-out of their plants in order to obtain the best possible economy of operation. The greatly diversified inventions requiring the use of electricity have much increased the demand for it. Existing plants are more and more pressed to the limit of their capacities, and must get the largest output from the available equipment. Increasing costs of coal continually tend to emphasise the importance of the fuel charge in the total costs of operation, and point to the necessity of greater economy in use. And a sentiment is growing more and more manifest that a high public spirit and the interests of the community require an economical use of natural resources.

It is appropriate, therefore, to take stock of the processes and methods available for improving steam-plant efficiency. The engineering periodicals exhibit a great interest in these questions and a large variety of improvements have been suggested. Usually the authors have devoted themselves to the careful and ingenious application of one or several methods of improving efficiency and have worked out the practical application of their ideas in particular cases. The purpose of the present article is to run over the whole field in a very general way, and to point out the limiting efficiencies attainable and show the lines along which the greatest margins for possible improvement lie. At the outset then practical and mechanical limitations will be disregarded in order to go first to the theoretically best economy. Fortunately this may be done in plain engineering language without the use of complicated mathematics. When this has been done it will be appropriate to discuss briefly the various difficulties in the way of going the limit at once. Such speculations bring up very interesting problems in thermodynamical mathematics, which have, nevertheless, been avoided as far as possible.

In the case of any particular installation the correct procedure would, of course, be to start with good practice and make such improvements as can be shown to be desirable. The object of the present paper will have been accomplished if, starting from the more remote ideal, it directs attention to the whole field open for selection and thus enables a more valuable choice to be made as to the best line of development to apply in a particular case.

The Ideal Conversion of Heat Energy.—Fundamentally conceived, the steam plant is simply a heat engine for converting fuel into saleable power. The textbooks outline certain theoretical facts about heat engines which it is convenient to recall at this time. A heat engine receives heat from a hot source, does work and rejects heat to a cold receiver. The process of combustion may be considered as the hot source and the condenser as the cold receiver. Heat is directly convertible into other forms of energy at a fixed theoretical rate known as the mechanical equivalent of heat or the heat equivalent of electric energy. If the ideal heat engine could convert all of the heat into work at this rate it would be necessary to reject the working substance devoid of all heat content, that is, at absolute zero. A working substance to carry the heat is, of course, essential. If at any time energy is reclaimed from the working substance, without other heat exchange, its availability to do work has been decreased a corresponding amount—that is, its absolute temperature has been changed. In fact, this idea is the whole basis of the definition of the thermodynamic scale of temperature. Since the temperature of a condenser can hardly be lowered to absolute zero, it is necessary for heat engines in general to do work, even under ideal circumstances, at an efficiency far less than unity. This efficiency is represented by the actual temperature drop of the working substance divided by what the drop might be if all the heat were abstracted, that is, initial absolute temperature. This is the well-known Carnot cycle efficiency and also the efficiency of any reversible engine.

As this idea of a reversible engine will come up again, it is well to recall it a little more carefully. It really must be the ideal engine, because if any other engine which might be thought more efficient—one which for a fixed amount of work done would have a smaller heat turnover—were used to drive the less efficient reversible engine as a heat pump, such a supposition would enable two isolated machines working together to have a net turnover of heat from a cold to a hot source. Such a condition is contrary to all experience, and the reversible engine with the Carnot efficiency is thus vindicated as the ideal engine. Furthermore, the textbooks go on to show not only that the Carnot efficiency cannot be exceeded, but that any cycle including an irreversible process is

* Paper read at the American Society of Mechanical Engineers, at their Annual Meeting, New York, December 3, to 6, 1923.

necessarily less efficient. An illustration may help to recall this point.

The transfer of heat from a furnace at 2,000 deg. F. to a boiler at 400 deg. F. is an irreversible process. Heat cannot be caused to flow by itself from the boiler to the hotter furnace. As a result of the decrease in temperature the availability of the heat energy in the steam at boiler temperature to do work is very much less than the theoretical availability of the same amount of heat energy in the furnace at the temperature of combustion. On the other hand, if the boiler absorbed the heat of the furnace at furnace temperature, such a process would be reversible, and would enable the steam to work with the higher thermodynamic efficiency which the high temperature would permit. In fact, the idea of availability to do work is synonymous with thermodynamic efficiency, and this idea of loss of availability or thermodynamic efficiency in connection with the irreversible step is the important thing to note at this time. Hence it is well to recall the various types of reversible process.

The Carnot cycle is made up of an isothermal expansion and an adiabatic expansion, followed by an isothermal compression and an adiabatic compression. The isothermal process or heat exchange without alteration of temperature can, of course, be worked either way, since no temperature drop is involved. The adiabatic process is reversible because it simply means no heat exchange to the outside at all, but simply a conversion of internal or heat energy into external or work energy. Ideally the isothermal is infinitely slow, and the adiabatic is correspondingly sudden in order to be reversible.

There is also the regenerative process in which all heat that passes out of the working substance during cooling is transferred at its own temperature to an auxiliary contraflow substance, so that it may be restored at its own temperature during a similar return process. This requires the infinite slowness of the isothermal and the supposition of a perfect contraflow heater always in contact with the working substance, so that the temperature differences between the working substance and the auxiliary substance are always infinitesimal.

Temperature Limits.—Certain very elementary conclusions are possible at once from this review of simple thermodynamic principles. It is desirable to have as cold a receiver as possible, and since there are practical limits to this coldness, it is also desirable to have the source of heat at as high a temperature as possible in order to give the widest possible operating range. These are the things that must be kept in mind when deciding on the efficiency of the ideal process.

With steam as a working substance and modern turbine construction it has been found that vacuums corresponding to temperatures between 70 deg. F. and 80 deg. F. are the best that can be obtained with the cooling water available. Of course, it is imaginable that during an Alaskan winter a turbine might be made to exhaust into an air-cooled condenser at a temperature well below 0 deg. F. Obviously in such a case the suitability of steam as a working substance would have to be considered in addition to the mere degree of coldness available.

Likewise, at the other end of the process it happens to be far easier to produce high temperatures than to utilise their advantage, because, in the case of steam, the vaporisation at a high temperature cannot be accomplished without confinement at an excessive pressure. Thus it is evident that the working temperature range is hedged around by various practical considerations which will need special consideration, and this will be given presently.

The Thermal Processes.—It is next important to consider the thermal processes and how closely they may be made to correspond with the ideal arrangement, that is, what sort of cycles can be used to the best advantage. It has been pointed out that the thermal processes should be either isothermal, adiabatic, or regenerative—that is in every case reversible. Beginning at the furnace, the fuel and air are brought together in the presence of heat. Combustion takes place and more heat is liberated. This is absorbed by the boiler and carried to the engine by the working substance. Finally such heat as has not been converted into work is rejected to the condenser. But in addition the burned gases escape up the stack.

The Ideal Furnace.—If, for the present, attention is confined to the furnace, it is plain that all the substance—fuel and air—which goes on to the grate and is heated must, in exactly the same quantity, disappear up the stack. Furthermore these substances which start at atmospheric temperature rise to the furnace temperature and then are returned to the atmosphere, eventually cooling to their initial condition. Considering the approach to, and exit from, the furnace, it is plain that equal quantities of substance rise on the one hand and fall on the other through equal ranges of temperature. This suggests the recovery of all the waste heat of the flue gases by regenerative air preheaters. Ideally these should be contraflow, with such surfaces and velocities that all the heat of the burned gases is transferred to the incoming air—and fuel also.

Next, considering the process of combustion, it may be regarded as a simple liberation of heat which occurs when the fuel and air are brought into contact at a high temperature. Suppose the fuel to be insulated from the air during pre-heating until the furnace temperature is reached, when combustion is permitted. Suppose the boiler to be so large that it will absorb the heat of combustion immediately without allowing any appreciable difference of temperature, the working substance being, in the ideal case, at the furnace temperature. This amounts to an isothermal transfer of heat and completes a reversible cycle in the furnace, at least from a thermodynamic point of view. The chemistry of combustion is another question. Still retaining the purely thermodynamic viewpoint, the furnace temperature is ideally arbitrary.

Furthermore, if the boiler is operated at a lower temperature than the furnace, the consequent loss of availability, according to the Carnot efficiency, must be charged against the boiler or its working substance and not against the furnace, since all the heat of combustion would still be transferred to the working substance. On the supposition of a perfect transfer of all the heat of the flue gases to the entering air and fuel, there would be no thermodynamic loss in the furnace, and if, in addition, an isothermal transfer of the heat of combustion to the boiler could occur, then the boiler could be included in the statement.

The Engine. Rankine Cycle not Ideal.—Turning now to the working substance in the engine, the steam is the first consideration. It is not necessary to discuss the Rankine cycle for steam. Instead of the adiabatic compression of the Carnot cycle an increase of pressure at constant volume is used, a process which is not reversible. The thermodynamic efficiency has been

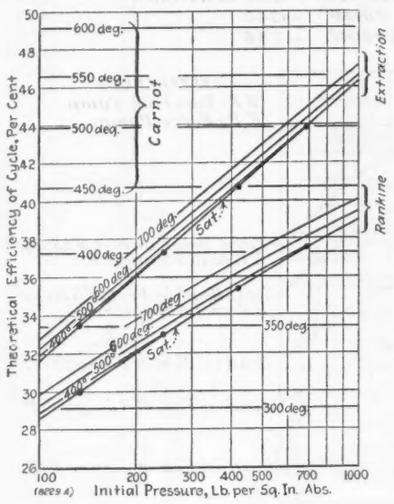


Fig. 1 Theoretical Efficiencies of Steam Cycles

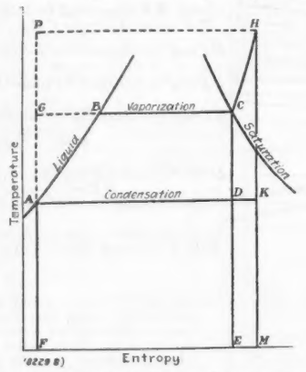


Fig. 2 Temperature-Entropy Diagram for Rankine Cycle with Superheating

calculated from the steam tables and plotted in Fig. 1 for dry saturated steam and for various initial temperatures and pressures. A glance at the diagram shows that the higher the temperature, that is, the higher the ideal efficiency, the farther does the Rankine cycle fall short of it.

This is especially true in the case of superheat, even though it improves the actual efficiency. The ideal efficiency rises enormously faster than the change in Rankine efficiency with superheat. With saturated steam the conversion from liquid to steam in the boiler, the expansion in the turbine, and the condensation are all reversible processes, only the process of heating the liquid being irreversible. On the other hand, with superheated steam the absorption of heat is no longer isothermal so that in this case two out of the four processes which go to make up the cycle are irreversible. Hence it is reasonable that the latter cycle should fall farther below the ideal. Moreover, it follows that for any particular temperature the less the superheat the higher will be the efficiency. In fact, for a particular temperature the efficiency is far the best if the pressure is high enough for the steam to be saturated.

The Extraction Cycle.—The question now arises as to what cycle can be used in order to cause the steam to turn over the heat in accordance with the best theoretical standards. Obviously the superheated-steam cycle is far from ideal. In fact, it is hard to justify the use of superheat from a purely theoretical viewpoint, although its application is thoroughly justified by a variety of practical reasons which will be discussed eventually. The Rankine cycle with saturated steam has only one process, the feed heating, which is not reversible. The idea of regenerative process consists in many small exchanges of heat occurring at successively different temperatures in infinitesimal steps. Suppose the steam extraction process be pushed to such a limit. It has been called a regenerative process, and this is true.

Suppose steam is extracted from every stage of the turbine and that the number of stages is indefinitely increased. If at each stage just enough steam is extracted to heat the feed the infinitesimal temperature difference, each bit of steam so extracted has gone through a cycle reversible except for the infinitely small temperature drops during the feed heating, and these infinitesimal temperature drops occur in an unlimited number of small steps as in any regenerative process. The boiler temperature can thus be reached within an infinitely small amount. In other words, the extraction cycle as a whole is entirely reversible in the limit.

In order to understand clearly the truth of this statement, the reversed cycle is traced as follows: Starting with a hot liquid, it is caused by a very small cooling to evaporate a part of itself isothermally at a reduced pressure, and that part is compressed adiabatically to the higher pressure and temperature in the boiler, where it gives up its heat isothermally and condenses into the hot liquid. Further cooling will evaporate a further quantity at a still lower pressure, and so on. If done in a very large number of steps the process may be rendered as close as desired to truly reversible.

The steam extraction cycle with saturated steam is thus, in the limit, a truly reversible process with the ideal efficiency of the Carnot cycle. Furthermore the demonstration has assumed only the pressure temperature relation of a wet vapour. It is good not only for steam, but equally correct for saturated ammonia or saturated mercury. However, it does not apply to the case of a superheated vapour. This is an important fact to understand clearly. The equivalence of the Carnot and extraction cycles was demonstrated in the days of the steam engine before the common use of superheat, and as a result the literature is not clear that the inference is true only for wet vapours and not for superheat. Furthermore it is easy to demonstrate this equivalence analytically on the basis of certain assumed algebraic relations of properties. Such demonstrations, using algebraic relations which are easily shown to be inexact, have failed to command confidence in the conclusion that the extraction cycle really is equal in the limit to the Carnot cycle.

This is about as far as abstract theory alone can go for the steam plant. The furnace and boiler have been imagined ideal by the use of regenerative air preheating with the flue gases, and the turbine has been imagined ideal by using saturated steam and heating the feed to boiler temperature by extraction. Thus the total margins for improvement are shown very clearly in Fig. 1, as explained before. The efficiency of the extraction cycle, including superheat, has been calculated according to the method outlined in the appendix. It now becomes necessary to narrow the ideal still further by taking up the practical matters which determine the temperature limits and see what are the relative margins to gain among the various methods of increasing the efficiency. There are two principal questions: First, the temperature limits; and, second, for established limits, how to approach as nearly as possible the ideal cycle.

The Upper Temperature Limit.—The upper temperature limit is determined by the materials of construction rather than by the furnace or the working substance. Turbine materials maintain their strength, roughly speaking, up to 700 deg. F. Turbine steels are usually good up to 800 deg. F., but the gradient of decrease in strength per degree rise of temperature becomes so steep at higher temperatures that only very low stresses are allowable. Conservative practice therefore places 750 deg. F. as the limit at the present time. It has been made clear that unless saturated steam is used, the efficiency of the process will fall far below the ideal. And with saturated steam these temperatures are above the critical and the pressure above 3,000 lb. per square inch. Both the excessive pressure and excessive moisture during expansion make it undesirable to use saturated steam at such temperatures. The curves for the extraction cycle and the Rankine cycle in Fig. 1. show very plainly the magnitude of this restriction due to the pressure of steam at saturation temperatures. The horizontal lines indicate Carnot efficiencies, and it should be noted that extraction efficiencies and Carnot efficiencies for particular temperatures, become equal at the saturation line.

The temperature-entropy diagram is useful for visualising the differences in the processes. Fig. 2 shows the Rankine cycle A B C D. The heat put in is represented by the area F A B C D E and the heat exhausted by the area A D E F. The Carnot cycle working between the same temperature limits has an efficiency which might be represented by certain areas constructed by drawing the lines A G and G B. For the same heat exhausted as in the Rankine cycle, the Carnot cycle would have to absorb heat F G C E and deliver work A G C D. It is plain, therefore, since the extraction cycle is equal in efficiency to the Carnot cycle, that it is represented by these areas, although only as areas, because the broken lines do not represent properties of the substance. Now with the superheated Rankine cycle the work area D C H K is added out of a heat addition of E C H M. The efficiency is raised because the added work area is a larger ratio of the added heat area than the original efficiency. But the work area of the Carnot cycle for the elevated temperature is represented by the area A P H K, so that the small addition D C H K is a ridiculously unsatisfactory

approach. Moreover the constant pressure line B C H is no longer isothermal. It is still possible to extract steam and heat the feedwater to the boiler temperature so that the efficiency may be made equal to and even slightly better than the Carnot efficiency for the saturation temperature G B C, but the feedwater cannot be heated to the upper temperature limit without encountering the excessive pressures already mentioned. Hence this large area between the saturation temperature and the upper temperature accounts for the failure of the superheat cycle to meet the requirements of an efficiency corresponding to its temperature.

The Advantage of High Pressure.—It should now be clear why there is a theoretical advantage in the use of high pressures, even though the temperature after superheating is already at the limit fixed by the materials. In order to get the thermodynamic advantage of the highest temperature reached the steam must be generated at that temperature, a process which is practicable only for wet steam and provided that the required pressure is maintained. Thus it is clear that, due to the nature of a vapour, the pressure is quite as important as the temperature. The curves of Fig. 1 set forth the very material rise in theoretical efficiency with increase of pressure at various initial total temperatures, and it should be noted that the increase is still more rapid when steam extraction is employed. These curves have been carried to 1,000 lb. per square inch absolute pressure. The manner of plotting on a logarithmic base renders the line so nearly straight that extrapolation is easy, although it may not be warranted. Even at 1,000 lb. per square inch the properties of steam are not known with precision. The pressure temperature relation is, however, well defined, and this shows that with saturated steam at 1,000 lb. per square inch absolute pressure, using the extraction cycle, the efficiency, high as it is, only equals the Carnot efficiency for 542 deg. F. and the temperature at the critical pressure itself is only about 700 deg. F.

The Binary Vapour Turbine.—The foregoing all points to the necessity of a substance whose vapour pressure will not be excessive at the temperature to which the materials of construction may be submitted. And this is the great advantage of the mercury turbine. Fig. 3 presents a temperature-entropy diagram for 1 lb. of steam with a similar diagram for 10 lb. of mercury drawn at the higher temperatures. In a particular machine the relative amounts of steam and mercury would be slightly different, depending on the temperature of the condenser-boiler. The ten-to-one ratio is convenient for plotting. The low pressure of 45 lb. per square inch at 800 deg. F. is very satisfactory, and the exhaust at 1 in. of mercury back pressure heats a steam boiler at 400 deg. F. and 250 lb. per square inch pressure, the steam from which may in turn be expanded to 1 in. of mercury back pressure. The entire working range of temperatures is from 800 deg. F. to 80 deg. F., and in each case wet vapours are used. In each case also extraction may, imaginably at least, be employed, although the mercury has so little liquid heat, as a glance at Fig. 3 shows, that its Rankine cycle is considerably nearer to ideal than is the case with steam. However, considering the ideal case, a simple scaling from Fig. 1 shows a theoretical increase of economy of the process just described of 37 per cent., as compared with good modern turbine practice using steam at 350 lb. per square inch pressure and 700 deg. F. temperature, and a saving of 28·7 per cent. as compared with the same turbine utilising the extraction cycle to the limit.

The mercury turbine has thus given a practicable way to reach the upper temperature limit as fixed by the strength of materials. The aim in that direction is now being directed at the materials of construction, and this is entirely correct.

The Lower Temperature Limit.—At the other end of the process, the condenser, the temperature limit is fixed by natural conditons. Cooling water sufficient to maintain a vacuum at 80 deg. F. is about as good as can usually be expected. However, it is the intention of this paper to look somewhat beyond immediate possibilities in a variety of directions. Fig. 3 also includes the liquid and saturation lines for ammonia, and if a turbine were supposed to be equipped with an ammonia condenser-boiler, then another turbine, an ammonia turbine, might as easily continue the process as the steam turbine continued the mercury process. If such a steam plant were located in the polar regions in winter so that the atmosphere could condense the ammonia at −25 deg. F., it would be possible to expand the ammonia to atmospheric pressure. Now if the feed is heated by extraction, as in the case of the steam and mercury, the efficiency would be such as to effect a saving of 45 per cent. over the case of a steam turbine working with the Rankine cycle at 350 lb. per square inch pressure and 700 deg. F. temperature.

It may also be noted here that sulphur dioxide could be used with less severe pressure than ammonia. This might be a matter for consideration if the process were adopted, and there is another reason than the efficiency of the process for the use of a refrigerating fluid for the last few stages. The capacity of the compound unit, being dependent on the last wheel of the steam turbine, could be very much increased if the steam expansion were stopped at a moderate vacuum and the remaining energy utilised in one of the suggested refrigerating fluids which have very much smaller specific volumes at the temperatures in question.

The Advantage of Steam Extraction.—Having thus discussed what the theoretical efficiency is and how various limitations determine what is ideal in any particular case, the next matter to consider is the utilitarian question of the value of the various improvements already instituted. The idea is to take up step by step various limitations that lie between the application of the perfectly general theory and present steam plant methods. The advantage of the mercury turbine has been pointed out. The theoretical advantage of steam extraction is shown in Fig. 1. The practical advantage depends on the number of heaters. Very roughly it may be said that, in comparison with no feed heating, the use of one heater will realise between a third and a-half of the full theoretical gain, and also, very roughly, that each additional heater will realise an improvement about half as large as the last preceding heater added to the system. It remains to discuss the advantage of or reason for superheating, re-superheating, drying, the economiser, air pre-heating and the use of auxiliary feedwater heaters.

The Advantages of Superheat.—The advantage of superheat, as mentioned before, is almost entirely a matter of practical application due to the limitation of a high initial pressure. The desired temperature cannot be attained with wet steam without incurring too high an initial pressure. Hence the pressure is pushed as high as possible and the slight advantage illustrated in Fig. 2 is realised by superheating. The theoretical value is plotted in Fig. 1 in terms of total temperatures. Fortunately, the use of superheat is attended with a non-thermodynamic improvement in efficiency which is roughly of the same order of magnitude as the theoretical

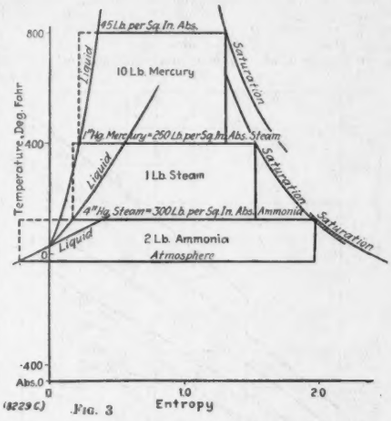


FIG. 3

TEMPERATURE-ENTROPY DIAGRAM FOR A COMBINATION OF MERCURY, STEAM, AND AMMONIA

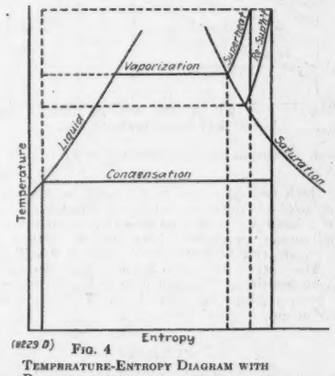


FIG. 4

TEMPERATURE-ENTROPY DIAGRAM WITH RESUPERHEATING

improvement. This is attributed to removal of moisture in the lower stages of the turbine. And still further the greater heat turnover per pound of steam results in an even greater reduction of water rate, which is advantageous in permitting a larger capacity rating of the machine, as will be discussed in another place.

In order to visualise these advantages it may be said, very roughly, that the theoretical gain in economy is about 1·5 per cent. for 100 deg. F. superheat, while the non-thermodynamic gain is about as much more, making an overall reduction of heat rate in the neighbourhood of 3 per cent. per 100 deg. of superheat. The reduction in water rate is, on the other hand, of the order of 8 per cent. per 100 deg. F. However, this must be clearly distinguished from an increase in the economy of operation of the plant. A reduction of water rate does not mean a corresponding reduction in the fuel rate because reductions in water rate usually entail a substantial increase in the heat per pound absorbed by the steam in the boiler.

Resuperheating.—The desirability of resuperheating is due largely to the same reasons that apply in the case of initial superheat. But the newness of the process makes it less easy to say what the gain may be beyond the theoretical amount. Fig. 4 shows at a glance that the cycle has been improved, roughly, by nearly the same degree as in the case of initial superheat as compared with saturated steam. The process is accompanied by a further reduction of water rate, as explained before, which is greater than corresponds with the reduction in heat rate. In passing, it may be noted that this resuperheating process is a sort of partial expansion under isothermal conditions. For instance, if the resuperheating should take place in each stage, this isothermal exansion might go on to exhaust pressure. There would be a slight additional gain in economy, but the efficiency of the process would not approach the efficiency of the Carnot cycle. The possibilities of practical application to any particular advantage are limited to about one or two steps of resuperheating.

Drying.—Drying may be accomplished by the same process as resuperheating, namely, by the addition of heat; but if the addition of heat is only sufficient to dry the steam without superheating it, the gain will be slight and due largely to increased mechanical efficiency in the process of energy conversion. On the other hand, if the drying is done by moisture abstraction, the gain is very appreciable. The moisture removed should be used for feedwater heating, and the practical rise of efficiency due to drier steam in the turbine should be realised. Here again it is impossible to say how much improvement can be realised until the method is put into practice. On the other hand, steam separators have been used for a long time, and the use of some form of separator in connection with extraction for feed heating would enable the removal of an especially wet sample of steam. In other words, instead of extracting a homogeneous sample, the extraction of all the moisture and only so much dry steam as might be required should enable one extraction drier used for feed heating to accomplish about as much gain in economy as, say two extraction heaters of the surface-condenser type. This is a very rough statement and depends for its truth on the possibility of satisfactorily operating the drying process.

The Economiser.—In all that has been said so far, there has appeared no place for an economiser. Indeed, as far as the theory goes, it appears to be anomalous. In considering the ideal furnace it was pointed out that flue-gas heat should be transferred to the entering air, and in considering the extraction cycle the logical source of feedwater heat was seen to be extracted steam. The economiser is intentionally aimed to extend the boiler process to a temperature below that corresponding to its pressure, i.e., to destroy its isothermal nature. But in all these cases where a substantial practice has grown up there is always a good commonsense reason sufficient to justify it at the time. Whether the practice should continue or not is always an appropriate question. The discharge of hot flue gas was a material waste. To pump cold water into a hot boiler was bad. And the transfer of heat from hot gas to water was a practical process well known, since it was taking place in every boiler; hence the economiser.

To secure an exchange of heat between large quantities of air with reasonable temperature differences is not so easy. The design of such apparatus is progressing at the present time, however, and installations of this nature have been made. It is certainly a process theoretically of such distinct value as to warrant serious attempts to accomplish its practical use. On the other hand, the success of this process will not in itself displace the economiser. The economiser works at temperatures roughly between 300 and 600 deg. F., whereas grate manufacturers prefer the air to enter the furnace at a temperature less than 300 deg. F. or certainly not much more. This is another very real limitation on the realisation of the ideal arrangement. The inability to utilise this flow of fluid for returning low-grade heat to the furnace means definitely a corresponding amount of waste. Here is a very good reason for pulverised fuel, if it will permit the use of very hot air going to the fire.

Air Preheating from the Economiser.—There are several alternative methods of connecting up these channels for the return of low-grade heat to the system. In examining them it should be kept in mind that the idea is always to have the heat transfer occur with the least possible temperature difference. That is, the process should be as nearly truly regenerative as possible.

One suggestion that has been made with a view to transferring the heat of the exhaust gases to the incoming air is to fill the economiser with an auxiliary hot-water heating system and pipe this to hot-water radiators in the inlet-air system. Such an arrangement would avoid the bulkiness of air-to-air heaters. But it does not commend itself on account of its complexity, although the contraflow feature of a regenerative process might be utilised at each end. Moreover the water would have to be confined under a very considerable pressure in order to attain the necessary temperature. Such a system would, however, leave the feedwater free to absorb the heat of extracted steam, and perhaps a more suitable auxiliary liquid than water could be selected for the transfer of the heat of the flue gases to the air.

Air Preheating with Extracted Steam.—The use of extracted steam for air preheating is another scheme. If the economiser is used at the same time, it will be observed that the recommended arrangements of the ideal process have been crossed. In detail, instead of recovering the low-grade heat by the two regenerative processes, flue gas to air and extracted steam to feedwater, the following processes have been substituted: Flue gas to feedwater and extracted steam to air. This is all right as far as it goes, but examination shows that the crisscross is not equivalent to the direct process. To make this plain it is noted that very roughly 2 lb. of air flow are required to 1 lb. of water, whereas the specific heat of the air is only about one-quarter as much as that of the water. In the upshot, then, the air circulation can carry back only about half as much heat per degree rise as the water circulation.—Moreover the limitation of grate temperature has been noted. It is thus evident that, even if all the air preheating should be done by extracted steam, it would still be desirable to extract more for feed heating.

Parallel Feed Heating.—Still another arrangement occurs to the author. The economiser must receive reasonably cold water in order to work efficiently

whereas the extraction process is not pushed to its limit unless it heats the water to boiler temperature. Present arrangements send the feedwater from the heaters to the economiser, thus dividing the available temperature range between the two heating devices. A more efficient way than to divide the temperature rise would be to divide the circulation into two very roughly equal parts (supposing pulverised fuel and no limitation on the air-preheating temperature). One branch of the system would be sent to the economiser as it comes from the hotwell and should enable the cooling of the flue gases to a materially lower temperature than with feedwater already preheated. The other branch of the system should be arranged to receive extracted steam, including appropriate amounts from the high-pressure stages, since these temperatures no longer detract from the action of the economiser. Similar amounts of extracted steam would be used for preheating the air. Such a process in perfect adjustment would approach the ideal process.

The House Turbine.—It is now time to discuss the use of a house turbine for feedwater heating. Very simply, if the house turbine has the same efficiency as the main units it is exactly equivalent to single-stage extraction. A house turbine is rarely as efficient as the main units, and generally means a less economical heat rate than extraction from the main units. On the other hand, it has certain advantages in the way of flexible adjustment that cause its use as a so-called "heat-balancer" element. By shifting the load on the house turbine the temperature of the feedwater may be regulated. It would be preferable to control the quantities extracted from the main units.

Steam Auxiliaries for Feed Heating.—If steam auxiliaries are used for other reasons, the exhaust heat from these may be used for feedwater heating. It is interesting to read descriptions of this common practice which seem to reflect an opinion that it is desirable to create a number of losses in order to have losses to recover. Steam auxiliaries are usually very inefficient as compared with the main unit and therefore not to be compared with motor drive. In consequence the use of such heat is a waste as compared with extraction from the main unit. Furthermore this heat is rarely added regeneratively but is dumped in at once, so that it reduces the ability to extract other steam more than in proportion to its own value.

The wisdom of having certain auxiliary drives duplicated by steam stand-bys in the interest of station reliability is not disputed at all. But it is maintained that the deliberate layout of a plant to heat the feedwater with such steam on the supposition that it is not lost is wrong because such a layout prevents the use of another arrangement which is more efficient. The heat returned to the system is not lost in itself, but for a given quantity of heat recirculated the auxiliaries can turn less into useful work than the main units. In other words, inefficient auxiliaries should not be placed in a station in order to provide feed heat which may be got from the more efficient main units.

Other Sources of Low-Grade Heat.—There are also several other sources of low-grade heat about the station which may be used for feed-heating purposes. Among these may be listed the following possibilities: the exhaust from the turbine high-pressure packings; the heat of the steam air ejectors; the heat of the bearings as recovered from the oil coolers; the generator losses as recovered in the generator cooling-air circulation. In such cases it is perfectly plain that the loss should not be created in order to get the heat. But having the heat it is allowable to use it, especially if it does not hinder the use of other heat. In every case the process should be as nearly regenerative as possible, and the final test of usefulness is the effect on the heat rate of the station as a whole when compared with the effect of some other arrangement.

The Final Criterion.—The importance of considering the station heat rate as a whole is not always appreciated. As soon as the boiler plant and the turbine plant are connected by the regenerative processes the whole station becomes a single thermodynamic unit, and it is no longer possible to judge its economy by considering separately the boiler and the turbine. For example, the economiser may be made extremely efficient at the expense of all feed heating by extraction. Or the reverse may happen so that there is excessive waste in the flue gases. The only safe rule is to look at the heat rate of the whole plant. Furthermore, in accepting such a criterion the electrical apparatus must not be lost sight of, nor the fixed charges. No one would consider for a moment doubling the investment to obtain a 1 per cent. increase in economy, and it is unwisdom of the same sort that focuses attention on any one element of the plant to the exclusion of its effect on the whole.

Capacity Rating.—In conclusion, it seems necessary to consider the effect of the various improvements on the capacity of a unit. This relation has been noted repeatedly in passing, and it is a fortunate circumstance that improvements in efficiency usually result in a greater power output from a given amount of working substance and thus tend to increase the rated capacity of a machine. In the case of a particular turbine of large size, the rating depends on the volume of steam passing the last wheel so that reductions of water rate, especially water rate at the last wheel, cause corresponding increases in the rated capacity of the turbine. The reduction of water rate with superheat has been mentioned. A similar reduction occurs with increased pressure. The effect of steam extraction is obviously to reduce the water rate at the last wheel. Recent advances in the rating of single turbine units have brought the importance of this subject to the front, and it seems necessary to point out here the great increase in capacity which theory alone provides in the case of machines using the improvements which have been discussed.

Fig. 5 is a chart of reciprocal water rates or theoretical capacities of kilowatt-hours per pound of steam at the condenser. Curves have been plotted for the Rankine cycle with superheat and for the extraction cycle. Although the specific volume at the exhaust does not vary greatly, very fine lines have been added to show its theoretical value. A comparison with Fig. 1 shows at a glance how much more rapidly the capacity rises than the efficiency. For instance from 130 lb. per square inch absolute and saturated steam with the Rankine cycle to 750 lb. per square inch and 750 deg. F. temperature with the extraction cycle, the capacity is just doubled while the economy is improved one-third. In this example the theoretical specific volume at the exhaust is the same in each case.

In the case of increased superheat at a fixed pressure the capacity rating of the machine increases less rapidly than the capacity per pound on account of the greater exhaust volume. On the other hand, with increased pressure at a constant superheat the capacity rating increases more rapidly than the capacity per pound because of the reduced exhaust volume. Generally speaking, increases of superheat have been accompanied by increases of pressure, so that exhaust specific volumes have been changed very little. It should therefore be plain that the continual increases of turbine

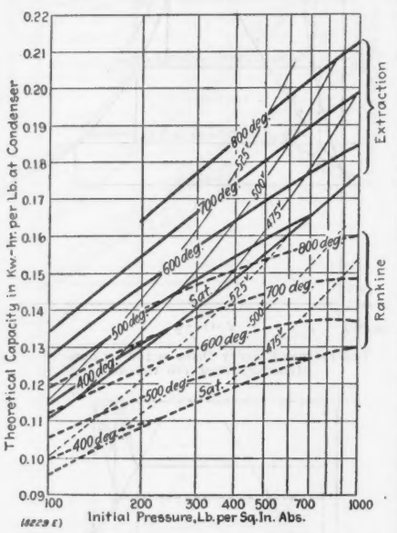


Fig. 5 Theoretical Capacities of Steam Cycles

rating which have occurred in the past decade without recourse to double-flow or multi-flow construction have been in a large degree due to true improvements in the thermodynamic processes. How much farther such improvements can be successfully carried is still to be seen. The author wishes to acknowledge the valuable critical suggestions of friends who have read the paper before printing, especially Dr. B. L. Newkirk and Mr. G. B. Warren.

APPENDIX.

The formulas for calculating the theoretical value of steam extraction as shown in Fig. 1 and Fig. 5 are given herewith. 1 lb. of steam is supposed to go to the condenser. At any pressure during expansion the quantity of working steam is $(1 + w)$ lb. At this pressure the corresponding total heat is H and liquid heat is h. The subscript 1 indicates the inital pressure and 2 the exhaust pressure. The formulas are expressed in terms of liquid heat at any pressure. e is the base of the Napierian system of logarithms.

The heat balance for any particular infinitesimal heater gives the relation:

$$d\,w\,(\mathrm{H} - h) = (1 + w)\,d\,h$$

Integrating, the amount of working substance is:

$$1 + w = e^{\int_{h_2}^{h} \frac{d\,h}{\mathrm{H} - h}}.$$

The energy E added to the Rankine cycle per pound of steam in the condenser, which is also the extra amount put in by the boiler per pound of steam in the condenser, is given by integrating the following expression for the work done by the steam going to any particular infinitesimal heater.

$$d\,\mathrm{E} = (\mathrm{H}_1 - \mathrm{H})\,d\,w = \frac{\mathrm{H}_1 - \mathrm{H}}{\mathrm{H} - h}\,(1 + w)\,d\,h$$

$$\mathrm{E} = \int_{h_2}^{h_1} \frac{\mathrm{H}_1 - \mathrm{H}}{\mathrm{H} - h}\,(1 + w)\,d\,h.$$

These formulas are used by tabulating or plotting the quantities as functions of the liquid heat. The integration is then performed graphically and the efficiencies and capacities are easily calculated.

CATALOGUES.

Electric Wiring.—The General Electric Company, Limited, Kingsway, London, W.C. 2, have issued a catalogue of their ordinary and water-tight wiring materials. The catalogue contains very full particulars of all the fittings required, and mentions the price of each item.

Locomotives.—Narrow-gauge steam and motor rail locomotives in a wide range of types and for all usual gauges are dealt with in a special catalogue received from Messrs. John Fowler (Leeds), Limited, 113, Cannon-street, London, E.C.4. A petrol-electric passenger and luggage car and an inspector's trolley are also illustrated and described.

Punching, Shearing and Cropping Machines.—Mr. Henry Pels, 40, Great Marlborough-street, London, W.1, has sent us two catalogues, one of hand-power machines for punching, shearing, cropping, plates, joists, &c., and another of single-ended and combined plate-splitting shears. The variety of types and sizes is very considerable and all are made with steel plate frames.

Hydraulic Turbines and Water Wheels.—A number of hydraulic turbines and water wheels of various designs are shown in a catalogue received from Messrs. Joseph J. Armfield and Co., Limited, Ringwood, Hants. The firm offers to send question sheets to inquirers, so that they may furnish particulars on which an estimate or advice can be framed in cases where the cost of sending an expert may not be warranted.

Screwing Machines.—A range of hand- or power-screwing machines for cutting threads on pipes up to 12 in. in diameter and on bolts up to 4 in. in diameter is dealt with in a catalogue received from Messrs. W. H. A. Robertson and Co., Limited, Bedford. The dies are of the chaser-form, opening automatically or by hand lever for the withdrawal of the work. Tapping and thread-rolling machines are also shown, and some useful data are added.

Scientific Instruments.—Messrs. Negretti and Zambra, 38, Holborn Viaduct, London, E.C.1, have sent us a set of trade publications, including notes dealing with the advantages of measuring temperatures in working industrial processes, &c., and a number of catalogues of thermometers, pyrometers, hydrometers, hygrometers, nautical instruments, &c. All the catalogues are evidently compiled with great care, the descriptions, notes and illustrations containing all necessary particulars and much useful information.

Heat Insulating Material.—A catalogue of heat insulating material in the form of slabs, sheets, ropes, cords, paper rolls, semi-circular and other sections, powder in sacks for moulding special forms, and shaped boxes for covering flanged joints, &c., has come to hand from Messrs. Hobdell Way and Co., Limited, 45, Church-street, Minories, London, E.1. The materials dealt with are suitable for covering steam pipes, boilers and steam-heated vessels generally, and also for insulating furnaces, ovens and cold storage chambers. Useful notes and data on the subject of heat insulation are included in the catalogue.

Agricultural Machinery.—Catalogues of finishing thrashing machines and auxiliary machines for feeding the crop into the thrashing machine, and for elevating straw and sheafs for stacking, and chaff cutting are to hand from Messrs. Clayton and Shuttleworth, Lincoln, who supply these machines with steam or oil engines if required. The machines, all of which are very clearly described, carry out the operations of cleaning, sorting and bagging the grain and cutting and cleaning the straw. The thrashing machine is made in three forms—portable, for attachment to a tractor or for fixing on brick supports, and it is made in about twelve sizes with capacities for dealing with 300 to 800 bushels per 10-hour day under average conditions. A table giving power required is included with the principal dimensions, weights and other data.

Electrical Machinery for Ships.—A catalogue of 80 pages quarto which will be of use and interest to marine engineers has come to hand from the Westinghouse Electric International Company, U.S.A., whose European office is at 2, Norfolk-street, Strand, London, W.C.2. The catalogue bears the title "The Marine Log," and its contents comprise a series of thirty-four articles dealing with the electric machinery of naval and merchant ships, tugs, dredgers, harbour lighters, shipyard auxiliaries, &c. An article by Mr. H. M. Southgate on the "United States Navy as an Industrial Asset," also included, is of considerable interest in showing that the construction of the American Navy involved the creation of large scale plant for forging, casting, machinery &c., this being done with the aid of government funds for experimental work.

Mining Developments in Shantung, China.—The coal mining centre at Tsaochuang Shantung province, is one of the most important and flourishing stations of the entire Tientsin-Pukow system, says the *China Weekly Review*. It is believed that more freight originates here (as distinguished from reshipped goods) than at any other place on the line except Tientsin. The mines at Tsaochuang produce about 700,000 tons of coal annually, supplying nearly all the coal used by the railway. The capacity of these mines will be more that doubled early next year, when a new shaft is to be equipped with the latest German mining machinery, including the most modern safety devices. The mining company plans further extensions, including the establishment of a Portland cement factory close to the mines.